Surveillance and Monitoring of Zoonoses

Report for the Department for International Development

Executive Summary

Effective surveillance is essential to understand pathogen epidemiology and consequently essential to the development of disease control programmes. The global spread of pandemic H1N1 and SARS has demonstrated the need for international cooperation in tackling the challenges of zoonoses and recent changes to the international health regulations and OIE guidelines place increasing emphasis upon the need for effective infectious disease surveillance and response capacities at the national level. Whilst there is growing consensus regarding the value of effective surveillance, it is clear that the need for enhanced surveillance capacity must be considered alongside other national and international funding priorities.

The objective of this study was to provide advice on future research and funding priorities with respect to the identification of potential zoonoses hotspots by critiquing the costs and benefits of surveillance for neglected and emerging zoonoses and identifying the usefulness of past investments in surveillance and monitoring systems.

To explore these objectives and address the terms of reference for this project we present a review that discusses:

- where on the global scale human and livestock disease surveillance is currently conducted;
- the evaluation of surveillance systems and options for determining cost-effectiveness;
- the issues surrounding the recording, reporting and response to surveillance data in developing countries;
- the use of innovative methods for the surveillance of zoonotic diseases;
- the available data on budgets and costs of zoonoses surveillance.

This study included review of both peer-reviewed and grey literatures with sixty-one named zoonosis surveillance systems identified and summarised. 30% and 28% of these systems included surveillance of only human or only animal populations respectively. Developing countries are more susceptible to infectious disease outbreaks, have less capacity to detect or report them, and are also least able to withstand the severe social and economic sanctions and consequences that often follow. However, we found that the developing world is currently severely underserved by surveillance systems for zoonoses.

Existing estimates of the direct and indirect economic losses associated with zoonotic disease outbreaks illustrate the scale of impact that these events can have. Estimates

for the direct costs of recent zoonoses outbreaks include $400 million for Nipah virus in Malaysia, $11,000 million for BSE in the UK, and $50-120,000 million for SARS globally (The World Bank, 2010).

This study identified several innovative approaches which can be applied to the surveillance of zoonoses including the use of mobile-phone based surveillance tools, participatory epidemiology, sentinel surveillance and syndromic surveillance. These approaches are designed to be flexible and cost-effective and all have the potential to achieve timely data collection and to enable access to and greater use of less traditional data sources. It is likely that the utility of these new approaches may be greatest in areas that are currently least well served by existing surveillance systems. For example, by the end of 2010 mobile phone cellular user rates for the developing world were predicted to reach 68%, as compared to internet user rates of 21% (ITU, 2011). Effectively, telecommunications companies have provided a global communications infrastructure that is inherently sustainable and can be utilised for disease surveillance purposes (IOM, 2007). The use of mobile phones also provides capacity for two-way communication and feedback of data to participants in surveillance, which is a critical element of system effectiveness and sustainability.

Key messages (& strength of evidence supporting them)
There is considerable scope for future investments in surveillance to improve our capacity to detect and control emerging zoonoses. To date, most investment has been directed towards predicting disease emergence hotspots, with much less attention given to control of endemic zoonoses. While gaps in surveillance capacity are of great importance in both cases, we argue that it will be more effective to focus resources on strengthening surveillance of endemic zoonoses. This will achieve multiple benefits, not only increasing the likelihood of detecting new and emerging zoonotic disease events, but also reducing the burden of endemic zoonoses, which have disproportionate negative impacts upon developing world countries and for which cost-effective control options already exist.

Review of surveillance systems

- Developing world countries are severely under-served by existing surveillance capacity. (Evidence - Strong)
- This lack of capacity and the resulting absence of data on the burden of zoonotic diseases leads to their ongoing neglect at the policy level. (Evidence - Strong)

- Few integrated surveillance systems exist, with the majority designed for the surveillance of human populations only or animal populations only. (Evidence - Strong)
- There is no standardised organisational model for the handling of zoonoses at the national and international levels in terms of policy-setting, management structures, surveillance design, laboratory capacity and data management. (Evidence - Strong)
- Most investments have focused on laboratory capacity and technical training, with relatively little attention given to the collection of field data, particularly at the interface between human and livestock populations. (Evidence - Moderate)

Evaluation of surveillance systems

- There are very few reported examples where zoonoses surveillance systems have been evaluated. (Evidence - Strong)
- Guidelines for the evaluation of surveillance systems exist, but have rarely been adopted in full. (Evidence - Strong)
- Efforts to assess the cost-effectiveness of investments in surveillance are currently limited by the absence of required data. (Evidence - Strong)
- Commonly used metrics for the evaluation of the cost-effectiveness of surveillance and control options, such as the DALY, underestimate the costs of neglected zoonotic diseases, perpetuating their neglect. (Evidence - Moderate)
- The specific costs and benefits of surveillance are extremely complex to estimate, partly because of the overlap of surveillance with other health system activities. (Evidence - Strong)
- Cost-effectiveness measures should be considered alongside other tools and approaches for priority-setting. (Evidence - Moderate)
- The provision of clear evidence of the cost-effectiveness of surveillance and control options for zoonoses does not necessarily result in the implementation of these options. (Evidence - Moderate)

Socioeconomic influences on disease reporting

- Zoonoses are often chronically under-reported and the consequences of under-reporting of both emerging and endemic zoonoses can be severe. (Evidence - Strong)

- Many factors can contribute to reporter unwillingness and/or inability to report, and these factors are likely to vary across socioeconomic groups and contexts. (Evidence - Strong)
- In the developing world context, the absence of a useful response to a disease report often acts as a major barrier to reporting. (Evidence - Moderate)
- Disease reporting can have considerable costs, including time and effort, as well as the potentially severe negative consequences of reporting e.g. trade and movement restrictions, destruction of animals. (Evidence - Strong)
- In combination, the absence of benefits and existence of costs, makes it understandable that individuals often chose not to report. (Evidence - Moderate)

Innovative surveillance approaches

- Innovative approaches and data collection tools can be employed to address a range of surveillance questions, but to be effective, they need to be incorporated within well-designed surveillance systems. (Evidence - Strong)
- To date, these techniques have mostly been applied in the human sector and there are few examples of their application to livestock or zoonoses surveillance, particularly in the developing world. (Evidence - Strong)
- The key capacity of these innovations lies in their flexibility and potential to enable better use of existing data sources, to overcome infrastructural deficiencies and address some of the gaps in existing surveillance capacity. (Evidence - Moderate)

Surveillance budgets

- The data available to quantify investments in surveillance and monitoring activities are very limited at both national and international levels. (Evidence - Strong)
- Surveillance is not a discrete activity and has considerable overlap with other health systems activities, both in terms of personnel and resources. As a consequence it is very difficult to define and allocate partial costs to a surveillance budget and few attempts have been made to do this. (Evidence - Strong)

Synthesis of findings

- The greatest ‘usefulness’ of past investment in the surveillance and monitoring of zoonoses has been in establishing relationships between disciplines and stakeholders, and in developing core capacities such as training of personnel, laboratory capacity and interdisciplinary dialogue that are inherently flexible and can enhance the surveillance of multiple disease threats (See Section 3.4). (Evidence - Moderate)

- Whilst research into the identification of future zoonosis emergence hotspots is certainly warranted, we do not yet have sufficient confidence in the predictive power of these techniques to justify their exclusive use for policy-setting. (Evidence - Moderate)
- There are compelling ethical and economic arguments for targeting resources towards endemic zoonoses. (Evidence - Strong)
- In many parts of the world we already have the capacity to detect and respond to disease outbreaks within a matter of days or even hours and we argue that the best way to tackle existing threats and to prepare for future emergence events is to invest in strengthening core capacities for disease detection and response in those areas where they are currently most deficient and bring them up to a common global standard. (Evidence - Moderate)

Key knowledge gaps and research priorities

The principal challenge encountered during this review has been the fundamental lack of data. In many parts of the world there is essentially no ongoing surveillance for many zoonoses, creating a major gap in our knowledge of what pathogens are present, where they occur, and the risks that they pose. This lack of data, which has historically contributed to the neglect of endemic zoonoses has huge implications for the assessment of future surveillance priorities. When surveillance programmes are implemented, they are only rarely evaluated and this creates challenges for the assessment of the value of past investments. In combination, these gaps in knowledge and capacity greatly complicate risk assessment and priority-setting exercises and there is a clear need to address these gaps so that better informed policy decisions can be made.

Future research effort should be focused at breaking the existing feedback cycle that perpetuates the circumstances where areas with weakest disease surveillance capacity coincide with areas of greatest zoonotic disease risk. To do this, it is important to focus upon enhancing capacity to respond to zoonoses. The endemic zoonoses have been described as low hanging fruit with cost-effective tools available for their for control and elimination (Molyneux, 2008; Molyneux et al., 2011). By focusing on enhancing capacity to respond to existing zoonotic pathogens, there is an opportunity to tackle the burden of endemic zoonoses in its own right whilst simultaneously demonstrating the importance of effective responses in incentivising surveillance. This would stimulate a culture of surveillance in those areas of the world where efforts are most needed, to tackle both endemic and emerging zoonotic threats.

Review of surveillance systems

- Existing surveillance capacity gaps in the developing world mean that policy-makers are currently provided with very little information with which to make informed decisions.
- Efforts to tackle existing data gaps must prioritise the collection of accurate field data at the ground level.
- Investments are probably best used to support surveillance schemes that are explicitly designed to integrate data from both animal and human populations, to address more than one zoonotic pathogen and that integrate control and response capacity from the outset.

Evaluation of surveillance systems

- Country and regional-level reviews of zoonoses surveillance systems need to be conducted to develop coherent national systems for surveillance that integrate zoonotic diseases e.g. adapting the method of Baker et al. (2010). Pilot assessments conducted for a small number of developing countries could provide a useful starting point.
- Separate estimates of the costs and benefits of surveillance should be made for a small number of national systems.
- Existing international regulations and guidelines should be adapted to include indicators of the costs and performance of surveillance systems.
- The development of priority-setting tools should be integrated with social science research into the decision-making processes and priorities of different stakeholders.

Socioeconomic influences on disease reporting

- Efforts to enhance disease reporting in developing countries should be based upon much greater understanding of why individuals choose to report disease, rather than focusing exclusively on the practical tools used.
- These efforts should focus on the grass-roots level at the bottom of the reporting pyramid, the fundamental source of all surveillance data.

- Social science-based research is required to appreciate and understand the different viewpoints, priorities and decision-making processes of stakeholders and to achieve better communication and implementation of existing data.
- Attempts to impose sanctions for poor reporting on the local scale are unlikely to be effective in the developing world and a more positive approach should be adopted to promote the value of reporting, celebrate successes and reward change.
- It is essential that stakeholder participation in surveillance systems is rewarded by a useful response.
- Investments targeted at strengthening capacity to control endemic zoonoses can be used to provide a tangible demonstration of the value of reporting and incentivise engagement with surveillance systems in which reporting and response are effectively linked.
- On the ground research is required to evaluate mechanisms for the provision of feedback and support to reporters and to assess what incentives work best for different stakeholders in different settings.

Innovative surveillance approaches

- Many innovative surveillance approaches hold great potential value for zoonoses surveillance but they have yet to be widely applied and there is a need for investment in field-trialling of these approaches to address current knowledge gaps.
- These trials should be targeted towards the development of mobile-phone based automated animal and human health data collection and handling systems that prioritise two-way communication.
- Sentinel and syndromic surveillance approaches can be used to enable the collection of essential baseline data on disease occurrence.

Surveillance budgets

- Accurate data on the costs of different surveillance options are essential to inform policy-making but at present, the availability of these data is very limited and there is a need for studies that design and field-test new tools for collecting data to allocate costs to zoonoses surveillance.
- The application of these tools and provision of data on surveillance costs should be conducted in parallel with assessments of surveillance system performance to enable evaluation of the value of investments made in relation to performance enhancements achieved.

Synthesis of findings

The lessons of past investment indicate that the greatest usefulness has been achieved through investment in core capacities that enhance the capacity for surveillance overall. It is therefore important that the best possible use is made of existing surveillance capacities and that future investment is directed towards achieving better integration of existing systems and to identifying and filling current gaps in coverage at interfaces between human and animal populations.

The current gaps in zoonoses surveillance capacity are predominantly focused in the developing world and there is a need to address the reasons for the underreporting in these regions. A key barrier to reporting is an absence of response when reports are made. The provision of a tangible response is essential to ensuring the sustainability of any surveillance system. To address global gaps in zoonoses surveillance capacity there is therefore a need to prioritise research into tackling the burden of existing endemic zoonoses for which effective response and control options exist. By investing in country level response and surveillance systems that help to control endemic zoonoses, progress can be made towards tackling the immediate health/development problems posed by zoonoses, demonstrating the practical benefits of surveillance and simultaneously helping to fill the gaps in the capacity of the global surveillance system to respond to future emerging threats.

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Abbreviations

ADSARS	**A**nimal **D**isease **S**urveillance **a**nd **R**esponse **S**ystem
AFHSC	**A**rmed **F**orces **H**ealth **S**urveillance **C**enter
APHIS	**A**nimal and **P**lant **H**ealth **I**nspection **S**ervice
BOSSS	**B**ovine **S**yndromic **S**urveillance **S**ystem
CBPP	**C**ontagious **B**ovine **P**leuropneumonia
CDC	**C**enters for **D**isease **C**ontrol and **P**revention
CEA	**C**ost **E**ffectiveness **A**nalysis
CEAH	**C**enters for **E**pidemiology and **A**nimal **H**ealth
CEPR	**C**entre for **E**mergency **P**reparedness and **R**esponse
CPD	**C**ontinuing **P**rofessional **D**evelopment
CSF	**C**erebrospinal **F**luid
DALY	**D**isability **A**djusted **L**ife **Y**ear
DEFRA	**D**epartment for **E**nvironment, **F**ood and **R**ural **A**ffairs
DfID	**D**epartment **f**or **I**nternational **D**evelopment
DoD	**D**epartment **o**f **D**efense
DTU Food	**D**anish National Food Institute
DVO	**D**istrict **V**eterinary **O**fficer
ECDC	**E**uropean **C**entre for **D**isease **P**revention and **C**ontrol
EFSA	**E**uropean **F**ood **S**afety **A**uthority
EID	**E**merging **I**nfectious **D**isease
EU	**E**uropean **U**nion
EQAS	**E**xternal **Q**uality **A**ssurance **S**ystem
FAO	**F**ood and **A**griculture **O**rganization of the United Nations
FDA	**F**ood and **D**rug **A**dministration

FMD	**F**oot and **M**outh **D**isease
GAO	United States **G**eneral **A**ccounting **O**ffice
GDACS	**G**lobal **D**isease **A**lert **C**oordinating **S**ystem
GDD	**G**lobal **D**isease **D**etection
GDP	**G**ross **D**omestic **P**roduct
GEIS	**G**lobal **E**merging **I**nfections **S**urveillance
GFN	**G**lobal **F**oodborne **I**nfections **N**etwork
GLEWS	**Gl**obal **E**arly **W**arning **S**ystem
GOARN	**G**lobal **O**utbreak **A**lert and **R**esponse **N**etwork
GPEI	**G**lobal **P**olio **E**radication **I**nitiative
GPHIN	**G**lobal **P**ublic **H**ealth **I**ntelligence **N**etwork
GSM	**G**lobal **S**ystem for **M**obile Communications
	(Originally **G**roupe **S**pécial **M**obile)
GVFI	**G**lobal **V**iral **F**orecasting **I**nc.
HPAI	**H**ighly **P**athogenic **A**vian **I**nfluenza
HSCC	**H**ealth **S**urveillance **C**oordinating **C**ommittee
	(Population and Public Health Branch, Health Canada)
IBRD	**I**nternational **B**ank for **R**econstruction and **D**evelopment
ICD-9	**I**nternational **C**lassification of **D**iseases - Ninth Revision
IDSAS	**I**nfectious **D**isease **S**urveillance and **A**nalysis **S**ystem
IDA	**I**nternational **D**evelopment **A**ssociation
IDSR	**I**ntegrated **D**isease **S**urveillance and **R**esponse **S**ystem
IHR	**I**nternational **H**ealth **R**egulations
INAP	**I**ntegrated **N**ational **A**ction **P**lan
IOM	**I**nstitutes **o**f **M**edicine
ISID	**I**nternational **S**ociety for **I**nfectious **D**iseases
IT	**I**nformation **T**echnology
ITU	**I**nternational **T**elecommunications **U**nion
JSON	**J**avaScript **O**bject **N**otation
MHS	**M**ilitary **H**ealth **S**ystem
MZCC	**M**editerranean **Z**oonoses **C**ontrol **C**entre
MZCP	**M**editerranean **Z**oonoses **C**ontrol **P**rogramme

NCASP	**N**ational **C**ompanion **A**nimal **S**urveillance **P**rogram
NDV	**N**ewcastle **D**isease **V**irus
NER	**N**amed **E**ntity **R**ecognition
NGO	**N**on-**g**overnmental **O**rganizations
NHA	**N**ational **H**ealth **A**ccounts
NII	**N**ational **I**nstitute of **I**nformatics
NPS	**N**ational **P**revention **S**ystem
NRC	United States **N**ational **R**esearch **C**ouncil
OIE	**O**ffice **I**nternational des **E**pizooties (World Organisation for Animal Health)
OWOH	**O**ne **W**orld **O**ne **H**ealth
PACE	**P**an-**A**frican Programme for the **C**ontrol of **E**pizootics
PARC	**P**an **A**frican **R**inderpest **C**ampaign
PDA	**P**ersonal **D**igital **A**ssistant
PDS	**P**articipatory **D**isease **S**urveillance
PDSR	**P**articipatory **D**isease **S**urveillance and **R**esponse
PE	**P**articipatory **E**pidemiology
PHEIC	**P**ublic **H**ealth **E**mergence of **I**nternational **C**oncern
PMM	**P**roMED-**M**ail
PPP	**P**ublic-**P**rivate **P**artnership
PPR	**P**este de **P**etits **R**uminants
PVS	**P**erformance of **V**eterinary **S**ervices
QALY	**Q**uality **A**djusted **L**ife **Y**ear
RSS	**R**eally **S**imple **S**yndication
RSVP-A	**R**apid **S**yndrome **V**alidation **P**roject - **A**nimal
RVC	**R**oyal **V**eterinary **C**ollege
RVF	**R**ift **V**alley **F**ever
SARS	**S**evere **A**cute **R**espiratory **S**yndrome
SMS	**S**hort **M**essage **S**ervice
UNICEF	**U**nited **N**ations **C**hildren's **F**und
USDA	**U**nited **S**tates **D**epartment of **A**griculture
VetPAD	**V**eterinary **P**ractitioner-**A**ided **D**isease Surveillance System

VLU	**V**eterinary **L**ivestock **U**nit
WAHID	**W**orld **A**nimal **H**ealth **I**nformation **D**atabase
WNV	**W**est **N**ile **V**irus
WHO	**W**orld **H**ealth **O**rganization

Chapter 1

Introduction

Surveillance is defined by the World Health Organization (WHO) as the ongoing systematic collection, collation, analysis and interpretation of data and the dissemination of information to those who need to know in order for action to be taken (WHO, 1997). As such, it is clear that surveillance is an essential pre-requisite for the understanding and control of infectious disease threats. Monitoring has been defined as "ongoing efforts to assess the health and disease status of a given population" (Salman, 2003). Monitoring is therefore an information gathering process that does not involve any action taken subsequent to gaining that information. In contrast, surveillance is considered a more active process and is a more inclusive term. Surveillance includes monitoring activities and a critical additional element of surveillance is that an identified response is made on the basis of the data generated through monitoring, to allow appropriate action to be taken.

The increasing recognition of the threat posed by emerging and re-emerging zoonoses and the awareness that this threat will persist and probably increase in the future, has prompted a multi-national reappraisal of the existing networks and systems of infectious disease surveillance. The importance of interactions between human, wildlife and domestic animal populations, the potential for the rapid global spread of emergent pathogens and appreciation of the need to carry out surveillance for as yet unknown pathogens demonstrates the necessity for novel, interdisciplinary surveillance strategies that are both more comprehensive and more flexible than any that have existed previously. At the same time there is also a growing awareness of the substantial burden of disease posed by endemic, neglected zoonotic pathogens (WHO and DFID, 2006; IOM and NRC, 2009; Perry et al., 2011). These diseases are neglected because they affect mainly poor and marginalised communities, and because few data exist to demonstrate their true burden. Irrespective of the policy focus on emerging or endemic threats, it is clear that good surveillance is required to tackle these disease challenges.

As a consequence there has been a proliferation of international collaborative schemes, workshops and reports that address the issues surrounding the global surveillance of infectious diseases in general and zoonoses specifically (King et al., 2004; FAO et al., 2008; IOM and NRC, 2009; The World Bank, 2010), and there is now a considerable but still largely aspirational literature on the way in which the global surveillance of infectious diseases in general and zoonoses in particular should be done (FAO et al., 2008; IOM and NRC, 2009; The World Bank, 2010).

Several key themes recur in this literature:

- The need for effective integration between human and animal surveillance, which is repeatedly identified as key to the successful surveillance of emerging infectious diseases (Morse, 1995; Murphy, 1998; Shears, 2000; Cleaveland et al., 2001; Woolhouse, 2002; Kuiken et al., 2005; Woolhouse and Gowtage-Sequeria, 2005; Kahn, 2006; FAO et al., 2008; IOM and NRC, 2009; The World Bank, 2010). The effective integration of the medical and veterinary disciplines may be particularly important in the developing world (Shears, 2000). Given both limited current infrastructure and resources for investment in both the human and animal sectors, an integrated approach to disease surveillance would encourage avoidance of duplicated effort and investment, whilst focusing on the ways in which these sectors could work together to make best use of any available resources (Shears, 2000). Across the developing world, people and animals live in close association and interact on a day-to-day basis and it is at least partly for this reason that the burden of endemic zoonoses is disproportionately focused upon the developing world (Maudlin et al., 2009). The existence of these close associations also suggests that integrated 'one health' strategies will have more intuitive application in these areas where there may be a greater instinctive understanding of the concepts and values of this approach.

- The need for open and rapid flow of information between disciplines and stakeholders. Surveillance is typically hierarchical and mostly reliant on multiple steps of information flow (e.g. from patient/livestock owner $\rightarrow$ healthcare worker/ veterinarian $\rightarrow$ district/regional health/veterinary facility $\rightarrow$ central government). The quality of surveillance data can potentially deteriorate at each step in this hierarchy resulting in limited capacity to inform appropriate, timely and effective responses.

- The need for the development and validation of novel approaches to surveillance that make the most use of the variety of data sources that exist in order to address the demands of the global and multi-species scope of zoonoses surveillance

The ways in which these key themes should and could be addressed will vary across different geographical and socioecological settings and the development of surveillance schemes must recognise this need for flexibility to avoid the imposition of locally inappropriate surveillance tools.

Zoonotic diseases often impose a dual burden on human health; they are a direct cause of disease, but also have impacts on livestock production and trade, damaging human livelihoods and well-being. Consequently, communities that live in close proximity with animals, and have a higher reliance on livestock for survival (usually the rural poor), bear the highest burden. As well as facing a higher existing burden of endemic zoonotic pathogens, the developing world has been identified as at particular disadvantage in terms of existing capacity to cope with the threat posed by emerging diseases (Shears, 2000; Breiman et al., 2007). High profile pathogen outbreaks in Africa such as viral haemorrhagic fevers and the spread of H5N1 influenza A in 2006-2007 have revealed the current shortcomings in surveillance capacity and prompted consideration of alternative strategies to develop core capacities vital to the surveillance of all potential disease threats (Shears, 2000; Breiman et al., 2007).

There is consensus that the surveillance of emerging infectious diseases, many of which are zoonotic, is a global public good but a smaller literature on the practical steps required to achieve this and considerable debate as to the financing mechanisms and sustainability of such a system. The current interest in the 'One Health' approach and surveillance of zoonoses specifically provides an opportunity to capitalise upon available resources to tackle both emerging threats and neglected zoonoses, which impose a considerable global burden.

This report compiles information from a wide range of sources and disciplines as well as a range of expert opinions to provide an overview of the current state of international zoonoses surveillance capacities. The following report sections describe reviews of active surveillance schemes for both human and animal disease from around the world and examine the issues surrounding each of the key themes of zoonoses surveillance; interdisciplinary cooperation, communication and data flow and novel surveillance approaches. Lessons learned from previous investments in surveillance and monitoring systems are outlined and approaches towards the identification of zoonoses hotspots and other surveillance strategies are discussed. The concluding section draws together the lessons from past activities and makes recommendations for future research priorities to enable improvements and make steps towards the development of the enhanced zoonosis surveillance systems that are needed.

Chapter 2

Review Methodology

This review focused upon current zoonoses surveillance activities. Given the considerable geographical and epidemiological scope of this activity, this is necessarily a broad-scale review, conducted to provide an overview of those surveillance activities that are being carried out and not an attempt to describe or evaluate the performance of individual systems in depth (See Chapter 4 for further discussion of surveillance system evaluation).

Throughout this report, many of the arguments made are illustrated with reference to six specific zoonotic diseases that were selected to illustrate and reflect the different geographic, policy and socioeconomic scales upon which zoonoses can impact. The selected zoonoses include both neglected zoonoses (brucellosis, rabies, echinococcosis, cysticercosis) and emerging or re-emerging zoonoses (HPAI and Rift Valley Fever (RVF)). The review methodologies described below were not restricted to these named pathogens but instead focused upon zoonoses as a whole. A more focused analysis in which the literatures specific to these six pathogens were reviewed is described further in Chapter 4.

The first step in the review exercise was the compilation of data from previously published reviews of the peer-reviewed literature on surveillance systems for zoonoses. This review was conducted in order to compare the outcomes of these previous reviews, identify any common conclusions and determine the best strategy for our systematic review.

One of the key findings of this initial survey of the peer-reviewed literature is that the majority of descriptions and evaluations of surveillance systems are in fact published in the grey literature. For this reason we also conducted a more extensive review focusing explicitly on this grey and literature, the methodology of which is described below. The results of these review exercises are discussed in the following chapter (See Chapter 3).

2.1 Previous reviews of zoonoses surveillance activities

There have been a number of recent publications of relevance to this review exercise (Bravata et al., 2004; Watkins et al., 2006; Hitchcock et al., 2007; Meynard et al., 2008; IOM and NRC, 2009; Vrbova et al., 2009; Baker et al., 2010; Vrbova et al., 2010), and two were of particular relevance. The review conducted by Bravata et al. (2004) aimed to describe surveillance systems of relevance to the early detection of bioterrorism-related diseases (Bravata et al., 2004). Although this review focused on systems for the detection of bioterrorism-related diseases it also included systems for naturally occurring diseases, if potentially useful for bioterrorism surveillance. As a consequence, the review did include emerging infections more generally and although not specifically focused upon zoonoses many of the findings of this review are applicable here. The review included 17510 articles and 8088 web sites and identified 115 systems, only 29 of which were in fact specifically designed for bioterrorism surveillance (Bravata et al., 2004).

A more recent review focused specifically on the surveillance of zoonoses. Vrbova et al. (2010) recently conducted a systematic review of the peer-reviewed literature to identify and characterise surveillance systems for emerging zoonoses (Vrbova et al., 2010). This review was motivated by three key questions, which are in line with the key questions that drive this current report:

- What public health surveillance initiatives for emerging zoonotic diseases exist worldwide?
- Have these surveillance activities been evaluated?
- What criteria were used to evaluate these surveillance initiatives?

The search of published literature (covering the period 1992-2006) used over 750 search terms based on terms for surveillance activities and a comprehensive list of zoonoses and identified a total of 2263 published articles. From these resources a total of 221 surveillance systems that met the study inclusion criteria were identified and summarised (Vrbova et al., 2009, 2010). The data extracted from each of the 221 systems included the purpose, location, population, year started, organisations involved, disease(s) under surveillance, whether the agent is known/defined, data collected, collection and analysis methods and evaluations performed (Vrbova et al., 2010). This review explicitly considered zoonoses that were classified as emerging (see Vrbova et al. (2010) for definition used) and may therefore have excluded those systems focusing on endemic pathogens. However, the status of pathogens as emerging was not classified on a case-by-case basis and because many zoonoses that are endemic in one country or region are also considered emerging in other settings it is unlikely that surveillance systems for endemic zoonoses were severely under-represented in this review.

2.2 Review of the grey literature on zoonoses surveillance activities

Surveillance systems must by definition be planned as relatively long-term ongoing activities and although the academic community may be involved in the design of such systems, it is more commonly the case that governments and non-governmental organisations (NGOs) are responsible for their practical implementation and sustainability. A consequence of this is that much of the literature regarding surveillance systems is not published in peer-reviewed formats (Hitchcock et al., 2007; Vrbova et al., 2010) but as commissioned reports and promotional/explanatory material produced by the organisations that are directly involved. Because of this, we conducted a review of surveillance activities that focused on this grey and largely online literature.

We used an inclusive definition of a surveillance system, defined by Hoinville et al. (2009) as '*the range of different surveillance activities that are able to produce data about the status of a particular disease in a population*', where, surveillance is '*the systematic, ongoing measurement, collection, collation, analysis, interpretation and timely*

Table 2.1: Description of the criteria used for the classification of all surveillance systems identified through the initial review of peer-reviewed and grey literature sources

Criterion	Description
Ongoing surveillance	Is the system currently active/ is surveillance ongoing?
International	Is the system international in scope? (*This includes both the geographic scope of the sources from which the data is collected and the composition and location of components of the system*)
Zoonoses	Does the system explicitly cover one or more zoonotic pathogens?
Multi-pathogen	Does the system cover one pathogen only or multiple pathogens?
Human Only	Does the system only include surveillance of human populations?
Animal Only	Does the system only include surveillance of animal populations?
Human & Animal	Does the system include surveillance of both human and animal populations?

dissemination of animal health related data essential for describing disease occurrence and for planning, implementation, and evaluation of disease control measures'. In this review, we also included the complementary surveillance of human health related data.

A two-stage search strategy was used. The first stage involved the initial identification of named surveillance schemes and systems. All systems referred to in the peer-reviewed literature reviewed above were added to a list of named systems and an additional preliminary search was conducted using Google, through which the first 100 references obtained from a search using the terms Global, Zoonoses and Surveillance were individually checked and any named surveillance systems identified were added to the list of named systems. Very broad initial inclusion/identification criteria were used in these initial searches, essentially only that the material regarding/referring to the surveillance system was written in English. The systems identified did not need to cover all activities of a surveillance system as defined above but did need to be ongoing and to include one or more of these activities. Any named surveillance system was then recorded and added to the database of systems to be characterised. In the second stage of the review, all identified systems entered into the database were then searched for explicitly using Google and categorised using the criteria given in Table 2.1.

The identified systems that were classified as ongoing, international in scope, covering zoonoses, covering multiple pathogens and including surveillance of both human and animal populations were summarised further. In each case, the data listed in Table 2.2 were extracted. To maximise the comparability of findings across reviews, these extracted data are based upon those used by Vrbova et al. (2010). The summaries of the identified surveillance systems are given in Appendix B.

The findings of these reviews are discussed in Chapter 3, the classification of all systems identified is given in Appendix B and the detailed summarie of the selected zoonosis surveillance systems are given in Appendix C. An additional targeted review exercise designed to focus specifically upon the cost-effectiveness of surveillance for zoonoses is described and discussed separately in Chapter 4.

Table 2.2: Description of the data extracted for ongoing surveillance systems that have international scope and include the surveillance of multiple pathogens (including at least 1 zoonosis) in both animals and humans

Item	Description
System name	The name of the surveillance system
Purpose	The purpose of the system as stated in the system material
Location/Coverage	The countries/continents over which the system functions
Setting	Any additional details regarding the setting of the system (e.g. ecosystem type?)
Population	A description of the population under surveillance
Year started	The year that the system started operating
Organisations involved	The organisations involved in the operation of the system
Syndromes and/or pathogens/diseases under surveillance	The pathogens/diseases/syndromes that the system monitors
Single/Multiple	Does the system collect data on just one pathogen/disease or on more than one?
Data collection	A summary of the type of data collected (e.g. laboratory test results, human symptoms, mortality statistics etc.)
Data handling and analysis	A summary of the handling and analysis of data received by the system, including assessments of validity etc.
Output/response	A summary of the actions taken as a consequence of 'case' detection by the surveillance system
Animal/Human/Both	Does the system collect data from human populations only, animal populations only or both?
Funding	What are the sources of funding for the system?

Chapter 3

Reviews of current human & livestock surveillance activities for zoonoses

3.1 Summary

This first section of the report addresses the task of reviewing current surveillance activities for both human and livestock diseases, and includes consideration of the geographical sites and regions in which these surveillance activities are being conducted and in which impacts are made. Reviews of both the published and grey literature are presented and the themes discussed include, the geographical distribution and coverage of existing surveillance systems, the integration of the human and animal health sectors, the involvement of the public and private sectors in surveillance, and the evaluation of surveillance systems. We also discuss approaches to the definition and identification of zoonoses hotspots.

The reviews presented indicate that although many identified surveillance systems are designed to achieve global coverage, there are fundamental gaps in surveillance capacity and developing world countries are currently severely under-served by existing surveillance systems. This gap has been exacerbated to some degree by the focus in recent

years upon the use of high-technology data transfer and manipulation techniques for surveillance. In those areas where communications infrastructures are limited, systems dependent upon the internet for example have little impact. At the same time, there has been a relative neglect of the grass roots collection of field data. Evidence of a trend towards greater integration between the human and animal sectors is presented. However, the majority of systems identified are still designed for the surveillance of a human population only or an animal population only. In addition, a recent focus of surveillance activities upon areas of human - wildlife interface is identified, particularly amongst those surveillance systems designed specifically to predict and detect emerging pathogens. Research into the identification of zoonoses hotspots has focused to date on the prediction of pathogen emergence and targeting of surveillance to those areas at which emergence is considered most likely. We argue that priority setting strategies should consider both emerging and endemic threats and that there is also a need to develop tools for the identification of areas of interface between humans and both livestock and wildlife populations at which the impacts and burden of zoonoses may be greatest. The importance of surveillance system evaluation is discussed but a severe lack of evaluation of existing surveillance systems is identified.

3.2 Integration between animal & human surveillance sectors

In the sample of published studies included in the analysis of zoonoses surveillance systems conducted by Vrbova et al. (2010), the number of classified systems that contained both animal and human data increased markedly in 2000 (year of publication) indicating that the surveillance community has responded to the call for integrated surveillance of both animal and human populations in the past decade (Figure 3.1) (Vrbova et al., 2010). However, only 19% of systems identified as zoonoses surveillance systems by Vrbova et al. (2010) actually covered both animals and humans and as a proportion of all of the studies included in this analysis, the proportion that include both animal and human surveillance has declined over time since 2000.

In the review of the grey literature a total of 61 named surveillance systems (accessible in English) were summarised. 45 of these were classified as ongoing and 40 of these

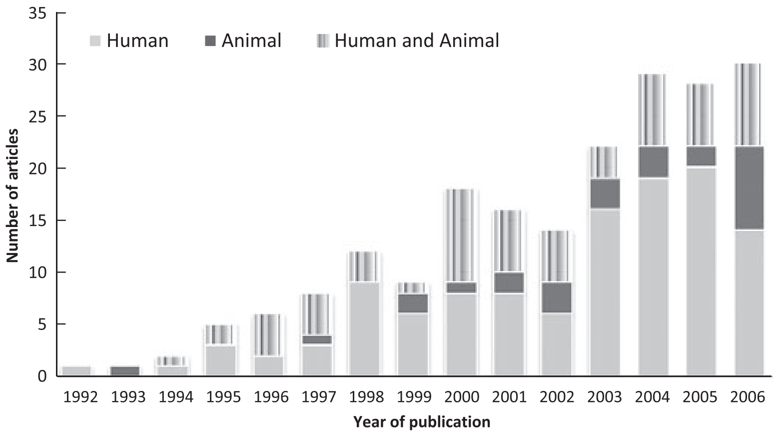

Figure 3.1: Peer-reviewed articles describing emerging zoonoses surveillance systems by year of publication between 1992 and 2006, by type of data in the system. Reproduced from Vrbova et al., 2010

Table 3.1: Summary of the classification of surveillance systems identified in two review exercises (Vrbova et al. 2010 & the present study), with respect to the population under surveillance

	Vrbova et al. (2010)	Present study
Human and animal surveillance	19 %	43 %
Human only	56 %	30 %
Animal only	25 %	28 %

systems covered one or more zoonosis (See Appendix B). As in the previous review by Vrbova et al. (2010), all of these ongoing systems were classified according to the types of population that they covered (both human and animal, human only, animal only) and the proportion of systems of each type identified in these two reviews are given in Table 3.1.

As compared to the earlier study, a considerably larger overall proportion of the systems identified in this current study included the surveillance of both animal and human populations, whilst a smaller proportion covered just human populations. Whilst this finding presents a promising sign of increased interdisciplinary integration it is quite probable that methodological differences explain the result. In contrast to the Vrbova et al. (2010) study, literature searches conducted for this study were based on the term zoonoses rather than the individual pathogens, and this search strategy may have meant that single-pathogen animal-only and human-only systems are under-represented in these results as compared to those of Vrbova et al. (2010). Indeed, only 28% of the systems identified in this review were also identified by Vrbova et al. (2010), indicating substantial influence of the search methodologies used. However, the review conducted by Vrbova et al. (2010) covers the period of 1992-2006 and since that date a number systems that are explicitly multi-pathogen and multi-population have been established (e.g. BioCaster, EpiSPIDER, GLEWS and HealthMap - see Appendix C). It is therefore possible that the increased proportion of systems seen in this review that include surveillance of both animal and human populations, does reflect a recent change in focus towards more integrated surveillance approaches.

A key rationale for conducting linked surveillance of animal and human populations is that animal cases caused by zoonotic pathogens often precede human infections (e.g. Ebola in great apes - Rouquet et al. (2005), West Nile Virus in crows - Mostashari et al. (2003); Eidson et al. (2005); Johnson et al. (2006)) and thus early detection of cases in the animal population could enable the prevention of human cases. The findings presented here indicate that the proportion of surveillance systems that include analysis of data from both human and animal populations may have risen over the last 5 years specifically. However, it is still the case that the majority of surveillance systems focus on either animals only or humans only. This finding therefore indicates that current surveillance practices are not still consistent with the ambition to undertake linked surveillance of animal and human populations and that current practices are unlikely to be sufficient to achieve the ambition of detecting zoonotic outbreaks in animals before they become a problem in human populations (IOM and NRC, 2009). Additional linkages between the animal and human surveillance communities must be forged to achieve this.

3.3 Geographic location of surveillance activities

Many of the surveillance systems identified in the review of the grey literature particularly have been established in the last decade, and 10 of the 13 named systems summarised in Appendix C are designed to have global coverage, a clear demonstration of a recognition of the increasing connectivity of different populations around the planet. However, the review conducted by Vrbova et al. (2010) indicated that amongst all identified systems, 40% were 'from' North America and 29% from Europe (Vrbova et al., 2010). Allowing for a publication language bias, these high proportions indicate a bias in the geographical bases of these surveillance systems towards the more developed countries of the northern hemisphere. This finding is corroborated by the data on the geographical basis and coverage of the zoonoses surveillance systems summarised in Appendix C. There remains a Northern hemisphere geographic bias in terms of the base of operations for many of these systems.

This is partly a consequence of the increased use of internet-based surveillance systems. Despite being apparently global in design, the actual coverage achieved by many recently developed web-based surveillance systems is essentially dependent upon the communications infrastructure that exists in countries/regions from which data might be generated. As a consequence, these 'global' systems still under-represent much of the developing world, across which communications infrastructure is still greatly limited (Figure 3.2). A recent analysis of data obtained through the HealthMap system for example found clear bias towards increased reporting from countries with more media outlets, more developed public health resources and greater electronic communications infrastructure (Brownstein et al., 2008). These internet based systems are therefore not helping to address the geographical gaps in coverage of existing surveillance systems. The less-developed regions of the world that include the more likely foci of disease emergence/spread still have the least developed surveillance coverage. The fact that most of the reports considered by systems such as HealthMap and other similar systems are in English (Brownstein et al., 2008), also contributes to this geographical bias and the poor coverage of non-English-speaking countries.

In addition to perpetuating gaps in where the data are obtained from, this geographical bias in data collection and reporting coverage has knock-on implications for where interventions informed by data are made. For endemic zoonoses especially, there are strong arguments that the relative neglect of these pathogens at the international policy level is caused in part by the lack of data on the burden that they impose, contributing to a damaging and self-reinforcing cycle of neglect (Maudlin et al., 2009). The under-reporting of zoonotic pathogens is discussed in more detail in Chapter 5 but it is important to recognise here that a lack of coverage in terms of data collection also has impacts for future priority setting and is likely to reinforce the under-coverage of particular areas in terms of both data availability and control or intervention impacts.

This review has identified a number of recent linked initiatives that are focusing particularly upon the interface between humans and wildlife, and designing systems to detect pathogen emergence at these interfaces in order to prevent predicted future pandemics. PREDICT, a five-year project funded by up to $75 million from USAID (USAID, 2009), is designed to develop global capacity to anticipate and prevent the emerging infections of the future and builds upon previously developed models of disease emergence hotspots (Jones et al., 2008). Similarly, Global Viral Forecasting Inc (GVFI) uses high-technology laboratory pathogen detection and discovery approaches to detect and monitor new emergent pathogens either before, or as they are transmitted from animals into humans and before they develop the capacity to transmit readily between humans (Nayar, 2009). The challenge for these programmes is to identify 'hotspots' at which the likelihood of pathogen emergence is particularly high. PREDICT is building upon previously developed spatial models of disease emergence risk to improve the quality of data concerning both the locations and species that should be targeted for sampling. In addition to integrating improved datasets concerning livestock density and land use patterns that have higher resolution than used previously, the programme is also designed to integrate data on mammal diversity, the phylogenetic distance of species from humans, the number of shared viruses between humans and each species and the previous sampling effort focused on these species (Daszak et al., 2010). However, even as the techniques for disease emergence hotspot detection/definition are refined, questions continue to be raised regarding the fundamental premise and assumptions of this kind of exercise. The predictors of disease emergence identified to date (e.g. Jones et al. (2008); Woolhouse and Gowtage-Sequeria (2005)) are such that there is essentially no location on the planet that does not fall into one or more risk categories. It is also the case that the accuracy and quality of the data that these models are based upon is questionable for areas of the developing work particularly and that the precision of

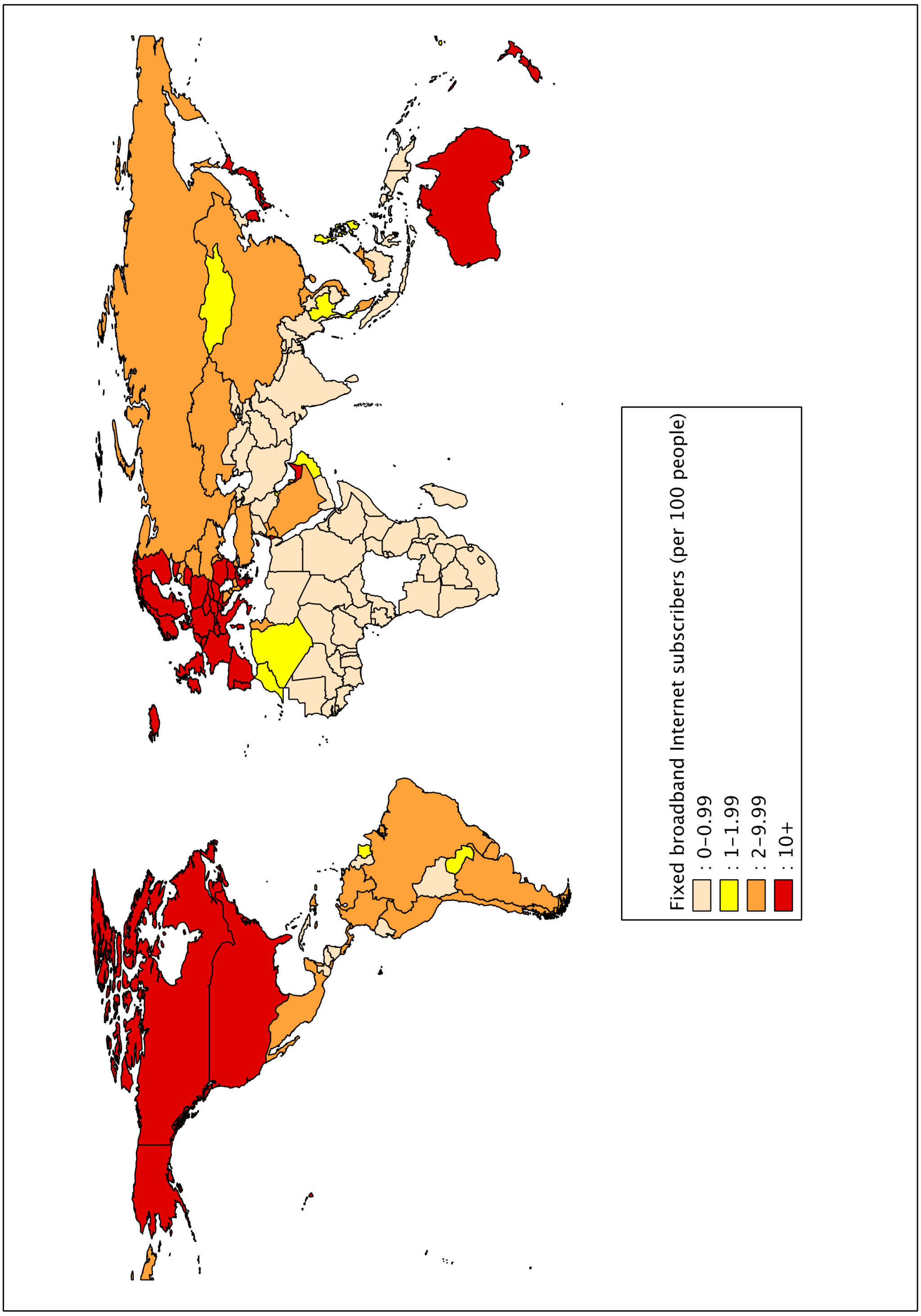

Figure 3.2: World map illustrating the number of fixed broadband internet subscribers (per 100 people). Blank (white) shading indicates no data available. Data source: International Telecommunication Union, World Telecommunication Development Report and database, and World Bank estimates

models designed to pinpoint particular regions will always be limited by these considerations. In addition, both the GVFI and PREDICT initiatives are focused on sampling wildlife populations and face potential problems of trying to determine which of the inevitably very large number of new viruses that will be identified from a given site, can/should be considered as pathogens/potential pathogens at all, and which subset of these might be the next emergent threat.

The defining feature of emerging infectious diseases is their unpredictability and it is recognised that emergence events can and do occur essentially anywhere. Rather than attempting therefore to predict the unpredictable and to focus efforts upon small regions it can be argued that the only way to prepare for the next emergence event is to think instead about surveillance that is truly global and to address capacity gaps on this scale so that emergence events can be detected and responded to wherever and whenever they occur.

As discussed above, the term disease hotspot is typically used in the context of disease emergence. However, a recent review of global livestock disease dynamics draws attention to the existence of different kinds of disease hotspot (Perry et al., 2011). Regions of the of the developing world that are undergoing significant and rapid intensification of livestock production are commonly discussed with relevance to disease emergence hotspots. In more traditional livestock-dependent smallholder settings though, low livestock densities, remoteness and slow change in husbandry practices reduce the likelihood that these settings will be important disease emergence hotspots and such regions are consequently described as 'cold spots' for disease dynamics and emergence (Perry et al., 2011). Perry et al. (2011) point out however, that these low-intensity, smallholder settings, which are the home of many of the 'bottom billion' of the global population, are hotspots for endemic diseases, disease epidemics and neglected tropical diseases. These are also the settings in which people are most dependent upon their livestock and consequently the most vulnerable to the various impacts of zoonotic diseases (Perry et al., 2011).

The identification of a causative agent is crucial in any outbreak investigation but there are currently clear geographic biases in the location and focus of diagnostic laboratories that can provide capacity in the surveillance of zoonoses (IOM and NRC, 2009). To detect and characterise novel outbreaks in particular, there is a need for laboratories that have a wide range of diagnostic skills and expertise, but, existing laboratory networks have traditionally been developed along agent-specific lines. However, a few of the laboratory-based surveillance systems included in this review (e.g. GFN & GPEI) do cover more than one pathogen, indicating a current trend away from this agent-based approach.

Progress towards greater integration between animal and human diagnostic laboratory capacity has been hindered by the apparently unfounded but widespread belief in the existence of regulations or recommendations that require the separation of animal and human laboratories. Both the risk of transmission of zoonotic pathogens to laboratory personnel and the potential for the generation of animal-human pathogens are cited as hazards in laboratories handling zoonoses. These hazards should of course be recognised but it is not the case that this recognition should logically translate into a recommendation to maintain a separation between human and animal diagnostic laboratories. First, it is of course true that extreme care should be taken to prevent exposures within laboratories. However, it is odd that this has become such a concern for laboratories handling zoonotic pathogens specifically when laboratories handling human pathogens exclusively face this potential every day and when there are well developed protocols to mitigate the risks of laboratory acquired infections. In a laboratory that routinely handles and diagnoses human pathogens there is nothing about zoonotic pathogens that inherently enhances their biosecurity requirements. Secondly, with respect to the risk of generation within the lab environment of recombinant pathogens, poor biosecurity and the cross-contamination of samples are fundamental problems in any lab, even those handling just one sample type and pathogen. Rather than ruling out the testing of animal samples in human labs or vice versa, risk assessments should be made on a pathogen by pathogen basis to ensure that adequate biosecurity and safety measures are in place to allow safe handling of a sample, irrespective of its ultimate origin.

Finally, it is also clear that the development of laboratory capacity to diagnose zoonoses is hampered by a current lack of clarity at the national and international levels as to which labs are mandated to handle zoonotic pathogen surveillance. Although calls for greater integration and capacity building have been made, there is currently no clear model for a workable global laboratory infrastructure for integrated diagnosis and reporting (IOM and NRC, 2009). The development of such a model and subsequent investment in a network of laboratories with enhanced diagnostic capacity for zoonoses would have clear benefits for the global surveillance of zoonoses. At the same time as building this technical capacity though, investors need to also recognise that the utility of a laboratory network is limited if the collection of field samples remains inadequate and that investment in technical capacity must be linked with investment in field surveillance capacity.

In addition to surveillance and control systems that are designed to detect potential future threats posed by zoonoses, there is also a need to focus surveillance activities at existing hotspots or more likely zones of endemic disease where zoonoses have considerable negative impacts upon the health and livelihoods of human populations today (Perry et al., 2011). The identification of these areas of in which zoonoses have current and tangible impacts should in theory be a much simpler task that the identification of likely hotspots for future disease emergence. However, this task is greatly hindered at present as a consequence of the geographic bias in surveillance activities that is described above (Perry et al., 2011). Without baseline data on what pathogens are present where and what impacts they have upon the health and wellbeing of human and animal populations in different areas, the identification of areas for priority investment is vulnerable to bias and such data are not currently available. Clearly therefore, there is a need for research effort that is focused at rectifying these deficits in surveillance and control programme coverage on the global scale. Factors associated with the under-reporting of zoonoses in developing countries particularly are explored in greater detail in Chapter 5 and the potential for innovative surveillance approaches such as participatory epidemiology to address these current deficits and to exploit existing local knowledge on disease burdens is discussed further in Chapter 6. In addition to prioritising future research action at those geographic areas that are currently least well served by existing surveillance systems there is also an argument for targeting effort and investment upon those areas of the world in which the pathogens that have the greatest current impacts upon human and animal communities are pathogens for which tried and tested methods of control already exist (Molyneux, 2008). This rationale for prioritisation, which includes consideration of the impact and cost-effectiveness of surveillance and control options for different pathogens has been described as the 'low hanging fruit' approach (Molyneux, 2008) because of its focus upon the 'reachable' surveillance and control goals. The efficacy of this kind of approach to the identification of priority areas of investment has been demonstrated for a number of important zoonoses (Molyneux, 2008).

Both this study and others have revealed the degree to which many surveillance systems increasingly involve the adoption of new technologies and approaches. These systems which are sometimes novel both in the techniques used and in the data-sources utilised include some of the web-based systems such as ProMED, GPHIN, HealthMap, BioCaster, EpiSpider and MEdiSys and some of the systems set up recently through collaboration of international networks such as GLEWS and PREDICT. Many of the surveillance systems summarised in Appendix C rely on sophisticated computer software to search a variety of web-based sources and extract relevant information. These systems provide very powerful tools that enable the rapid sharing, manipulation and representation of data. However, it must be recognised that such tools can only be as useful as they are designed to be if the raw data are of good quality and it can be argued that the focus on data manipulation systems can mean that the collection of good quality data is overlooked. This focus upon high-tech surveillance systems does therefore have the potential to further compound the degree to which developing country nations are left behind in terms of surveillance capacity and control investment.

The effort to make better use of existing data is clearly sensible though and the value of these innovative technological approaches are discussed further in Chapter 6, alongside other lower-technology but equally innovative approaches such as syndromic surveillance, the use of animal sentinels, participatory methods and risk-based techniques.

Surveillance systems must by definition be planned as relatively long-term ongoing activities and although the academic community may be involved in the design of such systems, it is more commonly the case that governments and non-governmental organisations (NGOs) are responsible for their oversight, practical implementation and sustainability. In the veterinary sector particularly though it is rarely the case that the public sector is able to maintain the cost of an extensive network of ground-level surveillance officers or disease reporters and in many cases there are strong pressures for rationalisation, devolution, decentralisation and privitisation of animal-health services particularly (FAO, 2002). For these reasons, arguments have been made for a division of activities between the public and private sectors, with the public sector focusing on i) the prevention, control or eradication of major epidemic diseases and ii) zoonotic diseases and veterinary public health, whilst the private sector focuses on more endemic diseases (FAO, 2002). Even within this kind of framework though, there is a need for close integration between sectors. The distinction between these activities is rarely clear-cut and the activities mandated to public sector organisations also effectively depend upon grass-roots data on disease incidence (of both endemic and epidemic diseases) that is most commonly observed by private sector health care practitioners. In Kenya for example, private sector providers undertake the majority of clinical work in the animal sector but are responsible for only 3.5% of surveillance reports received by the public sector (Daborn unpublished data). One key risk associated with dependence upon the private sector for the collection of grass-roots level stems from the fact that the distribution of private sector health-care providers is motivated by economic considerations rather than a principal focus upon the public good. As a consequence particular communities and regions may be under-innervated by private sector health care practitioners and therefore by the surveillance system as a whole. In developing countries, the access that rural populations have to services including human and animal population healthcare tends to be proportional to their proximity to major cities (FAO, 2002), leaving the most rural populations isolated from service provision. In combination, these factors lead to the under-coverage in surveillance terms of rural communities in developing country settings where livestock keeping is widespread and zoonotic risks are high but private practitioners are not attracted to establish or maintain services for animal or human health care provision.

3.4 Surveillance system evaluation & assessments of impacts

This review of current surveillance activities also reveals the very limited extent to which evaluations of systems are conducted, greatly complicating efforts to determine what impacts surveillance approaches have. This issue is discussed here and also expanded upon in Chapter 4 with particular reference to economic evaluations of systems. Several previous studies have identified shortcomings in the evaluation of existing surveillance systems (Bravata et al., 2004; Watkins et al., 2006; Meynard et al., 2008; Vrbova et al., 2010). Bravata et al. (2004) found very little evidence of evaluation of the surveillance systems discussed in their study and only 3 of the 115 identified systems had been evaluated in terms of both sensitivity and specificity. With respect to zoonoses specifically, Vrbova et al. (2010) found that only 17/221 surveillance systems for zoonoses had been evaluated to any degree (Vrbova et al., 2010). A particular deficit is the very limited data that are currently available on the costs of surveillance systems. As discussed further below (Chapter 4), this greatly limits the capacity to formally assess the cost-effectiveness and overall utility of different surveillance approaches. Less formally though, it has been widely stated that recent investments in surveillance and response activities, often prompted by pathogen-specific concerns, have resulted in less tangible, overall improvements to core surveillance capacities of relevance to a wide range of pathogens. Whilst up front investments in surveillance and response capacities such as vaccine stockpiles etc may be lost in the event that a threat does not materialise, the preparations made can have ‘collateral benefits’ in terms of developing organisational and institutional capacities to respond to disease threats more generally (Wilson et al., 2010). For example, a number of interdisciplinary groups and international networks, established to react to the threat posed by a single pathogen have subsequently been adapted and utilised for additional surveillance and response activities not within their original remit. On the human health side, the network of laboratories established through the Global Polio Eradication Initiative (GPEI) have expanded their scope to cover a range of other pathogens including the haemorrhagic fevers, Japanese encephalitis and SARS and this network has also contributed resources to national responses to H5N1 influenza (Hitchcock et al., 2007). Similarly, in the animal health sector, the Pan-African Programme for the Control of Epizootics (PACE), which aims at strengthening and establishing sustainable animal-disease surveillance across sub-Saharan Africa was established to build upon the achievements of the preceding single pathogen programme, the Pan African Rinderpest Campaign (PARC). Considering a zoonosis specifically, one of the greatest impacts of the global campaigns against H5N1 and then pH1N1 influenza has been the establishment of high-level international groupings such as the United Nations System Influenza Coordination (UNSIC) which has fostered communication between organisations such as the FAO, World Bank, OIE, WHO and UNICEF. Considerable efforts are now being made to maintain and extend these collaborations beyond influenza A to create a framework for reducing all disease risks at the animal-human-ecosystem interface and adopt a 'One World, One Health' approach (FAO et al., 2008; The World Bank, 2010). These decisions to build on existing capacities are themselves a demonstration of the value of previous investment in human resources and the creation and maintenance of working relationships between individuals and institutions.

A recent study by Chan et al. (2010) has attempted to quantify the impact of this apparent overall improvement in global surveillance capacities for detecting disease outbreaks. Using a database of all disease outbreaks reported to WHO in the period 1996 to 2009, the authors compiled data on the relative timing of the start of each outbreak, its initial detection and the communication of this finding to the public. Their analysis revealed overall improvements in the timeliness of both outbreak detection and reporting during this period and suggest that possible explanations for this improvement at the global scale include the formalisation of international collaborations and communications, the impact of updated regulations governing the reporting of public health emergencies of international concern and technological improvements that facilitate both detection and reporting (Chan et al., 2010). However, this study also found that the degree of these improvements varied considerably by region. In total 53% of all outbreaks included in the analysis were reported from Africa and the lags between the start of an outbreak and its detection then public communication were longest in this region (Chan et al., 2010). This finding clearly reveals the fact that 'global' disease surveillance remains fundamentally limited by the fundamental deficiencies in infrastructure in less-developed regions.

3.5 Discussion

The reviews presented in this section and surveillance system summaries provided in Appendix C indicate that there has been a clear focus in recent years upon building national and international mechanisms for coordination and exchange of surveillance data as well as significant investment in laboratory infrastructure. These linkages and surveillance system components are clearly essential and there is evidence that the investment to date has resulted in improvements in surveillance capacity at the global level (Chan et al., 2010). However, the essential foundation of the integrated approach required to tackle zoonoses research, surveillance, assessment and control is the collection of accurate and comprehensive field data (Chomel, 2003; King et al., 2004) and this on-the-ground data collection step has arguably been neglected in recent years. Any surveillance system will only be as strong as its weakest link and it is clear that despite considerable investment, problems remain with the detection and reporting of disease outbreaks in countries/regions with less well developed infrastructure (Brownstein et al., 2008, 2009; Chan et al., 2010; The World Bank, 2010). The development of tools for understanding and tackling the reasons for this deficit should be a priority for future investment.

3.6 Conclusions

The review has identified a number of gaps in current understanding and obstacles to the creation of effective surveillance systems for zoonoses. These gaps and obstacles are summarised below and suggestions as to future research priorities and ways forward are made in each case.

Limited coverage of developing world countries by current surveillance activities

Addressing this problem is an enormous task that will require the investment of significant resources provided by the international community for administration at the national level in those regions identified. Efforts to tackle existing imbalances must prioritise the collection of accurate field data at the ground level to achieve the broad geographical coverage necessary. In the subsequent sections of this report we discuss options for tackling some of the underlying reasons for current asymmetries in disease reporting practices (See Chapter 5) and the use of novel surveillance techniques that enable the collection and optimal use of those data sources that do already exist (See Chapter 6);

Limited integration of surveillance data from both animal and human populations The data presented indicate that the majority of surveillance systems are still entirely focused upon either the animal or human sectors in isolation. Further integration at all levels should continue to be encouraged and funders should provide preferential investment for schemes that are explicitly designed to integrate data form both sources. Similarly, surveillance systems that are designed to address more than one zoonotic pathogen and for which control and response capacity is emphasised from the outset should be prioritised;

There is no effective model for 'handling' zoonoses at the national level In terms of policy-setting, surveillance design, laboratory capacity and data management, zoonoses tend to fall in the gap between the animal and human health sectors, leading to an under-investment in their surveillance at all levels. To tackle this it is important for the international community to take the lead in devising expert-informed best-practice guidelines for the organisation and structure of an effective national level zoonosis surveillance policy. The development of these guidelines would be best conducted by an international and intersectoral body such as the recently established FAO-OIE-WHO collaboration;

There is a clear absence of evaluation of surveillance systems Many surveillance systems are apparently never evaluated, leading to an absence of data upon which to make surveillance policy choices. The development, agreement and application at the international scale of a set of standards by which all surveillance systems are measured would enable much better comparison of surveillance options. This may involve adaptation of existing performance indicators such as are currently included in the WHO IHR and OIE PVS for the human and animal sectors respectively, but will also require additional measures that are specifically targeted at assessing the integration between these disciplines that is essential for effective zoonosis surveillance;

Surveillance is not currently considered as an academic pursuit This point is illustrated by the absence of data for this review in the published academic literature. The design of surveillance systems particularly should be better informed by academic research into i) understanding of the sampling effort required to achieve stated surveillance aims and the feasibility of collecting sufficient data to detect changes in infection patterns with confidence and ii) the critical evaluation of surveillance systems (discussed further in the following section).

Chapter 4

Evaluating surveillance systems

4.1 Summary

An understanding of the costs and benefits of surveillance systems and mechanisms for evaluating these attributes are essential to inform the design of surveillance systems and the provision of investment that is targeted to achieve the most cost-effective surveillance and control. Comprehensive evaluation of the many systems that exist for the surveillance of zoonoses is beyond the scope of this review. Here, we provide an overview of the existing guidelines and techniques available for the evaluation of surveillance systems and a summary of the degree to which evaluations are currently conducted. We identify considerable shortcomings in current surveillance system evaluation practices. There is no consensus as to the best way to evaluate surveillance system, few evaluation procedures are flexible enough to be applied across different types of systems and very few surveillance systems are evaluated. In particular, the economic evaluation of surveillance systems for zoonosis is currently extremely limited. To tackle these problems, we argue that broad-scale measures of the cost and performance of surveillance systems should be incorporated within existing schemes for the assessment of human and animal health services at the national level (e.g. WHO NHA and IHR and OIE PVS) to enable comparison across countries and the identification of capacity and funding gaps. Comprehensive economic analyses of surveillance systems are currently not feasible and smaller scale studies should be conducted in the

first instance to devise and test appropriate methodologies for the assessment of the separate costs and benefits of zoonoses surveillance systems (WHO, 2005). Finally, it is important to recognise that even in those cases in which evaluations have been conducted and in which clear data on the value and efficacy of surveillance and control programmes have been provided, these data are not always sufficient in themselves to initiate a policy change. Considerable research is therefore required to appreciate and understand the different viewpoints, priorities and decision-making processes of stakeholders to achieve better communication and implementation of data regarding the effective surveillance and control of zoonotic diseases where available.

4.2 Guidelines for surveillance system evaluation

The evaluation of surveillance system performance provides an essential opportunity to consider the purpose, design, management and operation of a surveillance system and its success in meeting its stated aims (HSCC, 2004). Such evaluation can help to identify the successes and deficiencies of a given system, provide feedback for the continuing operation of a system and is of increasing importance as investment in surveillance systems increases (HSCC, 2004; Meynard et al., 2008). Numerous schemes for the evaluation of surveillance systems have been published (CDC, 1988, 2001, 2004; HSCC, 2004; WHO, 2005; Watkins et al., 2006; Meynard et al., 2008), including international standards provided by the WHO and OIE respectively for the evaluation of human and animal health surveillance systems specifically (e.g. WHO International Health Regulations (IHR) and the OIE performance of Veterinary Services Tool (PVS)).

Despite consensus amongst many of these published schemes on the broad themes that warrant assessment, there is currently no consistent approach to the evaluation of surveillance systems and perhaps understandably, when evaluations are conducted, the criteria used are often dependent upon the system attributes, data availability and the specific objectives of each evaluation (Centers for Epidemiology and Animal Health , CEAH; Watkins et al., 2006; Jajosky and Groseclose, 2004; Meynard et al., 2008; Vrbova et al., 2010). The inclusion within surveillance systems of both monitoring and response activities means that the timeliness of data availability and the rapid initiation of responses is a key attribute of any surveillance system. However, even the evaluation of this attribute is not widespread. Jajosky and Groseclose (2004) evaluated the timeliness of infectious disease surveillance systems in the US. They found very few published evaluations and those that existed used non-comparable methodologies. Their analysis also indicated that some long delays in reporting and variability across states limited the usefulness of the data collected and that these deficiencies can complicate the detection of aberrations in the data that might represent outbreak events (Jajosky and Groseclose, 2004). Additional recent surveys considering other evaluation criteria also reveal that the majority of surveillance systems for zoonoses and emerging infectious diseases more generally are apparently not evaluated, or at least that such evaluations are not published (Bravata et al., 2004; Vrbova et al., 2010). In fact, none of the zoonoses or animal disease specific surveillance systems identified through the review conducted by Bravata et al. (2004) had been described in a peer-reviewed evaluation.

Criticisms of existing evaluation approaches include a lack of adaptability to different contexts (Meynard et al., 2008), and the inability of systems that focus on one, or only a small number of attributes to address the interrelationships between different attributes and to identify gaps in coverage and performance (Drewe et al., *pers comm.*). Work to design a generic evaluation framework for surveillance systems is currently underway (Julian Drewe, *pers comm* re RVC & DEFRA collaboration). Given that the evaluation of any surveillance system must be dependent upon its purpose, which can be extremely variable and context specific, it can be argued that no single evaluation approach will be usefully applied to all surveillance systems (Watkins et al., 2006). The schemes that are currently being developed will have to be sufficiently flexible to accommodate this requirement whilst providing a core set of values or practices that enables the comparison of different approaches. In addition, there is a question as to whether or not surveillance systems designed specifically for zoonoses require a different or additional set of criteria for design and evaluation when compared with systems intended to keep endemic and non-infectious diseases under surveillance (Vrbova et al., 2010). One key added requirement must be the measurement of inter-sectoral interaction. Evaluation of systems designed for the surveillance of zoonoses will need, amongst other things, to evaluate the human and animal components of the system as well as the ways in which they are linked.

Approaches such as that recently proposed by Baker et al. (2010) may help to address these concerns about the applicability of previously described evaluation systems for zoonoses surveillance systems specifically. Baker et al. (2010) describe a framework and method used to review the infectious disease surveillance sector in New Zealand specifically and at the country level more generally. The proposed framework covers all steps in the review process from the planning of the review and its aims/scope, to the description/evaluation of systems identified, gap identification and finally to the communication and implementation of findings. There are no inherent limits to the application of this approach to other country, region or sector settings and the framework outlined could be used to conduct for example a review of zoonotic pathogen surveillance systems across multiple countries and regions (Baker *pers comm.*). The framework may however require some modification/optimisation for application to other country/sector settings (Baker et al., 2010) and this research should be prioritised to determine how valuable this approach is across different settings. The aim of this technique is to provide an overview rather than a detailed critique of each system but if applied at larger geographic scales the number of systems identified may become unmanageable. There are also several complex definitions to be made and applied and further work is required to determine if these can these be standardised to maintain relevance across settings (Baker et al., 2010). The key advantage of this review approach though is that it deliberately 'looks at the forest instead of the trees' (Baker et al., 2010), providing an overview of the interaction between systems, the gaps or redundancies that exist and the potential for additional integration and systems (Baker et al., 2010). Such an overview would be of great value in rationalising and consolidating the great diversity of systems that currently exist in order to effectively integrate and coordinate these at the global scale.

Ongoing evaluation is key to the assessment of which surveillance systems function best in which settings and the appropriateness of different systems in different contexts. However, the available evidence indicates considerable shortcomings in current evaluation practices. Evaluation does cost time and money, imposing its own burden upon the surveillance system (Meynard et al., 2008), and as a consequence it too needs to be thought through carefully. The economic evaluation of surveillance systems is very rarely mentioned in the evaluation schemes described above and this subject is considered specifically in the following section.

4.3 Economic evaluation of zoonoses surveillance systems

A key part of any evaluation of which surveillance techniques should be employed in a particular context must inevitably involve consideration of the cost of the surveillance system and the effectiveness of that system. Cost-effectiveness analysis (CEA), and economic evaluations more generally, are used extensively in medicine and public health research and policy to assess value for money by relating the costs and consequences of two or more health technologies (Soares and Dumville, 2008a). This approach can also be used to compare two or more surveillance approaches with the aim to promote an understanding of the return on money spent and to inform choices between different policy/funding options (Soares and Dumville, 2008b). Such economic approaches to decision-making in this context are arguably particularly relevant in light of the recent policy impetus and updates to both the IHR and OIE PVS which require or encourage countries to make additional efforts to enhance their surveillance and response capacities for infectious diseases. Making these changes will require external funding in many cases and economic evaluations can provide assessment of these efforts and help to justify investment in particularly cost-effective approaches (WHO, 2005).

4.4 Review of cost-effectiveness studies in the published literature for six named zoonotic pathogens

In this analysis, the peer-reviewed cost-effectiveness literature relating to six emerging and endemic zoonoses was classified and summarised. All searches of the peer-reviewed literature were conducted using MEDLINE with searches based on combinations of terms for the selected zoonotic diseases - brucellosis, rabies, echinococcosis, cysticercosis, influenza A and RVF - cost-effectiveness and surveillance search terms. For each pathogen, the results of two searches are presented:

- Search 1: Cost-benefit analysis AND named zoonosis
- Search 2: Cost-benefit analysis AND Population surveillance AND named zoonosis.

All of the references obtained through the respective Search 1 for each zoonosis were classified according to the criteria given in Table 4.1. All classifications were based on reading of the abstract rather than the full paper and inclusive definitions of both costs and benefits were used to allow consideration of non-monetary measures.

Table 4.1: Summary of the criteria used for the classification of references identified through the initial searches of the cost-effectiveness literature for each of six named zoonoses

Criterion
Does the paper present a description of one or more surveillance and/or response systems for the pathogen in question?
Does the paper present a description of the costs of the surveillance system (in this case not including response costs)? (e.g. staff time, transport, diagnostic testing)
Does the paper present a description of the costs of the response to the zoonoses? (e.g. control strategies including vaccination and treatment costs)
Does the paper present a description of the outcomes / consequences / benefits of the surveillance and response system?

The numbers of references identified through the literature searches for each pathogen are given in Table 4.2. The immediate result of this analysis indicated that there are very few published studies that assess the cost-effectiveness of surveillance, in fact only 13 of relevance to these selected zoonoses on the basis of these searches (Table 4.2).

A total of 439 references published between 1976 and 2010 were identified through the Search 1 for these six zoonoses (after removal of duplicates) and the vast majority of these related specifically to influenza A. Three hundred and forty seven references had

Table 4.2: Summary of literature searches conducted using MEDLINE to describe the existing literature on the cost-effectiveness of surveillance for selected zoonoses

Pathogen/Disease	Search 1 - n References	Search 2 - n References
Brucellosis	7	0
Cysticersosis	9	0
Echinococcus	15	1
Influenza A	376	10
Rabies	39	2
Rift Valley Fever	0	0

complete English language abstracts available and these were summarised according to the criteria in listed in Table 4.1. In keeping with the results of Search 2 (Table 4.2), only 17 of these references included any description of the costs of surveillance for these six zoonoses. In 16 of these cases, the references discussed the costs of different diagnostic test approaches and the remaining paper presented discussion of the costs of an electronic data storage and manipulation system. In contrast, 199 of the 347 abstracts reviewed (57%) included description of the costs of responding to the presence of these zoonoses, including evaluation of the costs of alternative control, vaccination and treatment options.

This review reveals the fundamental lack of existing data and published research into the costs of surveillance for zoonoses. The majority of the studies identified present data either on the economic burden imposed by the zoonotic pathogen in question, or on the costs of response to the presence of the pathogen. Whilst data on the costs of response are clearly valuable and should be considered alongside the costs of the surveillance system itself (WHO, 2005), there is a clear need for studies that quantify and compare surveillance costs specifically. Given the massive global investment in surveillance of H5N1 and pH1N1 influenza A over recent years, the small number of articles identified that address the cost-effectiveness of surveillance even for this pathogen is concerning. One paper published this year does provide an example of the kind of research in this field that could help to guide future surveillance investments. Knight-Jones et al. (2010) conducted an evaluation of the direct costs and effectiveness (in terms of probability of detecting H5N1 presence) of a range of different methods for the surveillance of H5N1 in the wild bird population on Lake Constance. They identified marked variation in the cost-effectiveness of different methodologies and their modelling approach also enabled explicit exploration of the influence of a range of important factors upon the efficacy and costs of different methods. Whilst this study represents an example of the kind of work that needs to be done to enable proper CEA-based evaluation of different surveillance approaches, the authors themselves clearly state the difficulties of extrapolating findings from this study to other contexts (Knight-Jones et al., 2010). They argue that a more complete understanding of the relationships between costs and sample size and between sample size and sensitivity would be required to allow prediction of cost-effectiveness of different strategies at different sites (Knight-Jones et al., 2010), further illustrating the limitations of current knowledge in this field.

There are currently only a very small number of studies that have attempted to evaluate either the costs or benefits of any surveillance systems (not including response components) and for this reason, the feasibility of undertaking comprehensive economic evaluations of surveillance systems for zoonoses is unfortunately limited at present (WHO, 2005).

4.5 Framework for the economic evaluation of surveillance systems

The findings presented above reveal a marked deficiency in the types of economic evaluation studies needed to determine the cost-effectiveness of different surveillance approaches for zoonoses. Here, we provide a brief framework to guide the kinds of economic evaluation studies that would assist in this evaluation.

Economic evaluations of surveillance strategies will primarily be performed as a decision theoretic exercise to inform surveillance choices and budget allocations. The form of analysis performed will depend on the specific form of decision to be made. For example, if surveillance choices are to be made within a defined budget then cost effectiveness analysis needs only to assess the relative benefits of the available surveillance choices; it is not necessary to estimate absolute cost benefit or cost effectiveness on a general scale. However if budget for surveillance competes with budget for other areas of expenditure such as defence, education or development it is necessary to estimate cost effectiveness either in absolute monetary units or on an effectiveness scale that allows comparison with choices available outside zoonotic disease surveillance.

Within a defined budget, cost effectiveness analysis attempts to estimate the costs and benefits of different, competing choices. Under some assumptions this may be simplified if either the costs or benefits are assumed to be equivalent. For example, if two surveillance systems are considered to produce equivalent benefits, choice can be based simply on cost, a strategy referred to as 'cost-minimisation'. Unfortunately the majority of competing choices will differ in both costs and benefits so both aspects will need to be estimated to allow comparison and rational choice.

An important consequence of accepting that economic evaluation has its utility in informing decisions, is that it requires that analysis is based on incremental changes to costs and benefits. In this framework, the total 'burden' of disease is irrelevant to the consideration of a surveillance strategy that will impact on it. The economic evaluation of the strategy is solely concerned with the change in costs of adopting the strategy and the incremental benefits that result (which may be a reduction in mortality and morbidity or a increased productivity of an agricultural system). Diseases of estimated high total burden may be poor choices for surveillance targets if there will be little impact on their burden. Conversely diseases of low relative global impact may be amenable to a large burden reduction at relatively low cost. This argument has been made for example in support of greater investment in the 'neglected tropical diseases' for which cheap and effective drugs and control programmes exist and for which a given investment may yield considerably greater impact and effectiveness as compared to less readily controlled diseases such as malaria and HIV (Molyneux, 2008). This point reveals the need for consideration of economic evaluations within a wider decision-making framework. There are other rationales for setting surveillance and response priorities and these are likely to vary depending on viewpoint and context. A recent study that explored the guiding principles for priority setting amongst health care workers and development partners in Uganda, found that the majority of health care workers prioritised disease severity whilst development partners preferred cost-effectiveness (Kapiriri et al., 2004). The pattern of preference for prioritisation based on disease severity is observed in a range of resource-poor settings but may be at odds with evaluations of other stakeholders based on cost-effectiveness analyses (Kapiriri et al., 2004).

The following sections describe the types of cost based analyses available:

4.5.1 Cost minimisation

Where two or more strategies of estimated or assumed equal benefits are available the analysis will be solely confined to estimating the cost of applying the strategy. A rational choice will then be to adopt the cheaper strategy.

4.5.2 Cost effectiveness

If costs and benefits vary but benefits are measurable on an equivalent scale, cost effectiveness analysis may be used to compare competing alternatives. An example would be strategies to detect incidence of a single disease in the same population at the same time in the infection cycle (e.g. Knight-Jones et al. (2010)). The alternative strategies may then be compared in terms of cost per case detected. Although measures of effectiveness such as infections detected or prevented are useful when assessing the cost-effectiveness of two or more approaches to the surveillance of a particular disease, they do not allow for comparison between treatments or diseases when the units in which effectiveness is measured will be different (Soares and Dumville, 2008b).

4.5.3 Cost utility analysis

Frequently, competing strategies will produce benefits that may not be directly comparable. Utility and other scales may be used to translate different benefits onto a single scale for comparison. Examples include quality adjusted life years (QALY) used for evaluation of health technologies and disability adjusted life years (DALY) used for estimation of the impact of disease and benefits of interventions (e.g. for Rabies, Knobel et al. (2005); echinococcus, Budke et al. (2005); brucellosis, Roth et al. (2003)).

Translation of the quantified impacts of a surveillance strategy to a suitable scale for comparison can be difficult as it requires development of a scale of values of disease consequence and such measures can be subject to bias and/or deliberate hijack based on political agendas (Arnesen and Nord, 1999). It is also argued that the use of the DALY as a near-universal tool for priority setting results in the systematic undervaluation of the neglected tropical diseases (many of which are zoonoses), because of the fundamental lack of data upon which to base DALY estimates for these diseases (Maudlin et al., 2009). There are currently no equivalent scales or measures of utility that can be applied to compare impacts upon animal health and productivity, although efforts to develop a measure of disease impact and intervention benefit upon animal-owners in terms of animal productivity are currently underway, e.g. the Productivity Adjusted Usable Life year (PAULY) (Lafrance et al, unpublished data).

4.5.4 Cost benefit analysis

Not withstanding the technical difficulties involved, cost benefit analysis offers the most useful methodology to inform economic decision-making. Surveillance system benefits are translated to a monetary scale allowing direct comparison of costs and benefits both between competing surveillance strategies and more generally across any budget allocation or setting choice. The challenge of cost benefit analysis is specifically the translation to a monetary scale. This requires a monetary value to be placed on all of the non-monetary benefits (and losses) of each competing surveillance system. Whilst the notion of applying such a value to health outcomes may appear controversial and even objectionable it is important to appreciate that an implicit valuation is applied to health outcomes every time a health intervention or human disease surveillance choice is made. Cost benefit analysis attempts to make this process transparent and explicit. Established techniques exist to determine monetary benefits including human capital (economic impact of disease on human productivity), revealed preference analysis (econometric analysis of monetary choice made) and stated preference analysis (a survey based approach using hypothetical health benefit versus monetary trade-offs) (Drummond et al., 1997; Soares and Dumville, 2008a).

It is critical with all forms of economic evaluation that they are considered within an appropriate and clearly defined set of constraints. Constraints will include:

4.5.5 Viewpoint

The economic viewpoint of a decision delineates the agents that will bear the costs and enjoy the benefits. Typical viewpoints may be a government, a community or society as a whole. For an economic evaluation to be useful the viewpoint will need to be consistent across all the competing alternatives. Otherwise costs and benefits may be selectively included and excluded from the assessment of different strategies. The consideration of a societal viewpoint is particularly relevant as many costs such as transfer payments will be excluded. If in doubt, the broadest viewpoint should generally be adopted (Drummond et al., 1997).

4.5.6 Time period & discounting

Costs and benefits of surveillance strategies will be measured or estimated over a defined period. This period needs to be appropriate for the decision to be informed. The choice of time period is a difficult issue and has to balance the needs of the decision-maker, the time course of the interventions and the life-cycle of the benefits (see WHO (2005) for more discussion). As costs and benefits may not necessarily occur simultaneously in time it is important that analyses consider the time value of money and benefits. This will normally require discounting of future costs and future benefits at an appropriate rate. The choice of discounting rate (and mathematical form) is potentially difficult as differences in the timing of costs and benefits between competing strategies may mean that a change in discount rate will affect which strategies appear more cost effective.

4.6 Discussion

There is evidence that very few surveillance systems currently include ongoing evaluation and that the costs and benefits of different surveillance systems are rarely quantified. There are though, several obvious reasons for this, the clearest being the difficulties associated with the assessments that would be required. To do a CEA for a hypothetical surveillance system for a zoonotic pathogen you would need to measure/quantify the costs of the surveillance system, the benefits of the surveillance and response components of that system and be able to relate these two components to each other (WHO, 2005). At present, the feasibility of undertaking such an analysis is severely limited by the absence of the requisite data (WHO, 2005).

To address this, it has been argued that initial studies should be conducted to estimate the costs and benefits of surveillance systems separately (WHO, 2005) but even this is not straightforward. In those attempts that have been made to quantify the costs of both animal and human sector surveillance systems (Civic Consulting, 2009; Somda et al., 2009) (and see Chapter 7) numerous challenges were encountered, including difficulties in defining and standardising the scope and responsibilities of a surveillance system and very limited availability of budget data (particularly at sub-national levels) (Civic Consulting, 2009; Somda et al., 2009). Similarly, attempts to quantify the benefits of surveillance are hampered by difficulties in quantifying both the impacts of disease upon animal and human populations and in developing measures of surveillance system impacts and therefore benefits (Carabin et al., 2005; The World Bank, 2010).

Arguments have been made that existing international regulations and guidelines could be adapted to enable collection of data on both the costs and benefits of surveillance to enable these assessments at the national level. In the veterinary sector, it has been recommended that further investment in the OIE PVS tool could generate quantitative data on both expenditure and quality benchmarks. An aggregated PVS measure would potentially allow comparison of national prevention systems (NPS) expenditures with the degree to which the NPS adheres to OIE International Standards. Whilst any such summary measure would represent a considerable simplification of a complex situation, it could be used to provide guidance to countries for allocating their expenditure on veterinary national disease prevention systems effectively and efficiently (Civic Consulting, 2009). In the human sector, the WHO National Health Accounts (NHA) provide a platform through which relatively detailed data on surveillance costs could be generated and measures of adherence with the IHR 2005 could be used as an analogous indicator of surveillance system performance. Ultimately, as methodologies for these assessments are developed, more detailed techniques for evaluating surveillance costs and benefits and for integrating these across the human and animal sectors will be required to fully assess the performance of integrated animal and human surveillance systems at the national level. In the first instance though, we advocate the development of the aggregated surveillance system costs and performance measures that could be developed through modification of existing WHO and OIE systems.

Cost-based evaluations alone will not always be the most appropriate or useful methods for assessing different surveillance options. For pathogens that have pandemic potential, such as influenza A or SARS for example, it is argued that standard CEA techniques are ill-equipped to estimate the cost effectiveness and cost benefit of interventions to control these pathogens because of the great complexity of quantifying the potentially enormous impacts of these pathogens, not only at the individual level, but upon the wider society and economy (Beutels et al., 2008). CEA techniques are likely to be more useful for the assessment and justification of surveillance systems for endemic zoonoses but even in these cases, other considerations must be taken into account. The principal value of cost based evaluations is not that they provide a definitive basis for a decision but that through conducting the evaluation, a structured framework for decision-making is applied that allows and encourages decision-makers to explicitly consider all assumptions made and all relevant components of the decision in perspective to their relative contributions and subsequent effects (Koplan, 1985).

Advocates of CEA must also recognise that there is an existing and compelling literature that indicates that investments in the surveillance and prevention of a number of neglected endemic zoonoses would lead to overall benefits for both human and animal populations (both in terms of direct economic costs and also on other more 'humanitarian' scales) (e.g. Budke et al. (2005); Carabin et al. (2005); Knobel et al. (2005); Zinsstag et al. (2007); Lembo et al. (2010)). However, despite the publication of these data, the investments required to achieve these improvements have not been made. This demonstrates that there are clearly other decision-making processes and considerations involved in priority setting when in comes to the investments that could be made in surveillance and response to zoonoses. In addition to providing demonstration of the nature and scale of the problem, investment is clearly also required into two parallel areas: firstly in understanding these processes in order to determine how and when these interventions could be made and secondly in trial initiatives to develop and demonstrate the efficacy and value of practical measures to tackle these problems.

International interest in surveillance for zoonoses, and the ways that this can be done has grown very rapidly, but it can be argued that academic thinking about the best ways to evaluate these approaches has not yet caught up. At present therefore, despite significant investment in zoonoses surveillance systems, there remains a fundamental deficit in our knowledge of appropriate surveillance system design and evaluation techniques for emerging infectious diseases including zoonoses (Watkins et al., 2006; Vrbova et al., 2009). As a consequence, decision-makers currently lack an evidence base on which to choose effective surveillance systems (WHO, 2005; Vrbova et al., 2010). When considering which surveillance approaches should be applied when and where, the cost of the system is a highly influential consideration. However, CEA type approaches are most suited to making a decision between two or more alternative approaches to tackling a discrete and well-defined question or to looking at incremental benefits. In addition to considering costs and other mechanisms for assessing the value of surveillance and response, evaluation should also include assessment of the various methods through which surveillance data are made available and presented to a variety of stakeholders to determine what methods best facilitate good decision-making in different scenarios (Bravata et al., 2004).

4.7 Conclusions

There is currently no consistent approach to the evaluation of the performance of surveillance systems and very few systems are apparently evaluated. This is particularly true with respect to economic evaluations of the relationship between the costs and benefits of different surveillance options. As a consequence, policy-makers are currently provided with very little information with which to make informed decisions about which surveillance options should be applied in which situations. To address this problem and move towards more rational and evidence-based decision-making processes in this field there is a considerable need for the coordinated collection of data on both the costs and performance of surveillance systems that are comparable across systems and settings. In addition, there is a need to better understand the ways in which data on these measures are communicated and interpreted by policy-makers and donors to ensure better communications of findings and implementation of control systems where feasible and appropriate.

Several gaps in current approaches to surveillance system evaluation have been identified:

- there is little consistency amongst the existing guidelines that are available for the evaluation of surveillance systems, no consensus approach, few standardised measures and systems are both complex and data intensive;
- partly as a consequence of this, very few surveillance systems have been evaluated;
- this lack of evaluation is particularly severe in the case of economic evaluations of zoonoses surveillance systems;
- commonly-used tools for assessing the utility of surveillance and control, such as the DALY, underestimate the costs of neglected tropical diseases, perpetuating a cycle of insufficient resource investment in these diseases;
- the provision of data on the financial and humanitarian benefits of effective surveillance and control of zoonoses are not in themselves always sufficient to achieve policy changes and a more complete understanding of the interpretations of these data by stakeholders and the decision-making processes and constraints involved are required;
- with respect to emerging pathogens with pandemic potential, the viewpoints of national governments and the international community and their assessments of the relative costs and benefits associated with different surveillance approaches to these pathogens may differ, reducing the likelihood of successful cooperation.

The following strategies for addressing these gaps and limitations are proposed:

- country-level and global reviews of the respective zoonosis surveillance sectors should be conducted by adapting the review method outlined by Baker et al. (2010). The efficacy of this approach should be determined initially through pilot assessments made for a small number of developing world countries;
- fundamental data deficiencies currently limit the feasibility of comprehensive CEA analysis of surveillance systems and we support arguments made previously (WHO, 2005) that initial studies should be conducted to estimate the cost and benefits of surveillance systems separately in the first instance - the preliminary work in this area should concentrate on evaluations at the national level;
- existing international regulations and guidelines - e.g. the WHO NHA and IHR and OIE PVS - should be adapted to incorporate collection of data on the costs and performance of surveillance systems at the national level - this process should include identification of indicators of success that can be realistically measured and that will demonstrate even small improvements in disease control that can motivate further surveillance effort;
- priority-assessment tools should be developed that would build upon the assessments of surveillance capacities and gaps advocated above. If standardised and applied across national and international scales, the data generated will enable appreciation of the different viewpoints and priorities of the national and international groups that must be involved in a surveillance system and help with the identification of areas of consensus;
- the development of tools for priority setting should take place in parallel with social science research into decision-making processes amongst different policy-makers and stakeholders across different administrative levels and socioeconomic settings to inform better communication and application of surveillance data.

Chapter 5

Socioeconomic influences upon disease recording, reporting & response in developing countries

5.1 Summary

In this section of the report we provide an analysis of the issues surrounding the recording, reporting and acting upon surveillance data, with particular emphasis upon developing country settings and socioeconomic influences upon reporting practices. Generating surveillance data is vital to enable response and control activities but zoonoses are often severely under-reported in developing countries especially. There are many factors that contribute to this under-reporting and whilst the relative importance of these factors varies in each particular case they may often act in combination to stifle the collection and distribution of accurate and comprehensive data (summarised in Figure 5.1). The consequences of the under-reporting of both emerging and endemic pathogens can be severe. An inability or unwillingness to detect and report emerging pathogens can lead to delays in the recognition of a threat, which in turn greatly reduces the likelihood of successful containment. The under-reporting of endemic zoonoses leads to an under-appreciation of the scale of the problem, which then leads to provision of

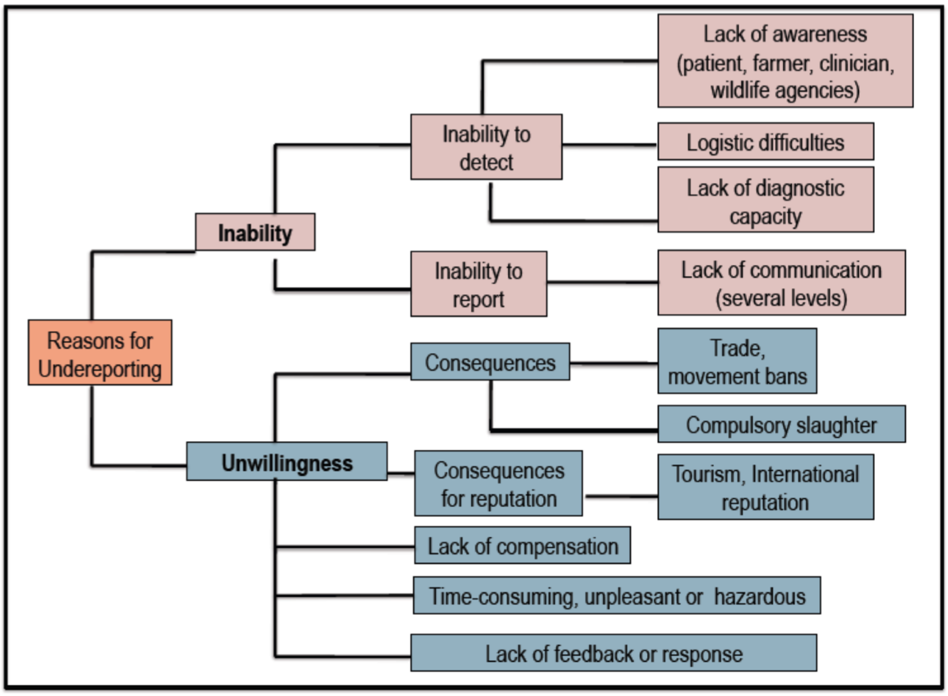

Figure 5.1: Summary of reasons for under-reporting of diseases. Adapted from World Bank, 2010

inadequate resources and investment, contributing to a cycle of neglect (Maudlin et al., 2009). It is clearly important to try to understand the reasons for current recording and reporting failures in order to try to tackle them. We identify several barriers that operate at different levels of the reporting pyramid and propose a focus of both research activities and policy adjustments upon incentivising reporting by investing in the provision of responses to disease reports to achieve improvements in surveillance and control overall.

5.2 On the ground disease detection & reporting

However sophisticated the data collation and transmission mechanisms, the key strength of any surveillance system is in the quality and coverage of data collected and reported at the lower levels of the reporting system (Shears, 2000). In the developing world in particular, there are fundamental deficiencies at the foundation of many surveillance

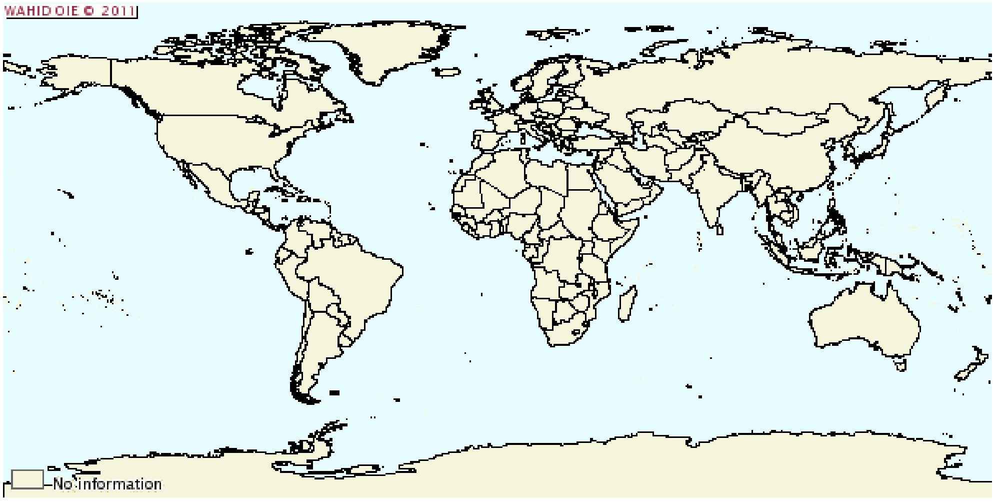

Figure 5.2: Map of global distribution of bovine brucellosis in the period July-December 2010. Accessed from the OIE WAHID website, Feb 2011. The cream colour indicates countries for which no information is available.

systems i.e. the detection and recording of disease cases on the ground. Several studies have documented the scale of under-reporting for a range of zoonoses in humans. The true number of human rabies cases in sub-Saharan Africa for example, is thought to be at least 100 times higher than official figures reported to the WHO (Knobel et al., 2005). In terms of the detection and reporting of zoonoses in the animal sector, a simple look at the OIE world animal health information database (WAHID) interface reveals the lack of reported data from the majority of countries for many zoonoses (Figure 5.2).

Two important preconditions for an effective reporting system are an awareness of the targeted disease(s) among everyone involved and the availability of specific diagnostic methods (Danuser and Aubert, 2007; Baker et al., 2010). The lack of either or both can have profound influences upon detection and reporting in both animal and human populations. Many zoonoses present in humans as non-specific febrile illnesses, which are frequently misdiagnosed, often as malaria (Reyburn et al., 2004; Maudlin et al., 2009). A study conducted in Tanzania revealed that the awareness amongst clinicians about the clinical presentation, diagnosis and epidemiology of many zoonoses was low (John et al., 2008). There are few reliable rapid diagnostic tests for zoonoses and even when such tests do exist, they are rarely available at local medical facilities (Maudlin et al., 2009). When considering the reporting of endemic animal diseases, the familiarity of animal keepers with certain common illnesses and their acceptance of these as a 'normal' state of affairs greatly reduces the likelihood that such cases would ever be reported (The World Bank, 2010).

More generally, the problems associated with poor surveillance in developing countries reflect systemic issues of healthcare services provision: overburdened staff lacking in skills, motivation, support and financial resources (Rumisha et al., 2007; Streefland et al., 1999). The hierarchical nature of traditional surveillance structures requires multiple layers of communication within and between sectors (that depend on locale specific governance structures and decentralisation practices). At every communication step the quantity and quality of information being conveyed may deteriorate, which reduces the likelihood of initiating an appropriate, timely and effective response. On the ground disease detection and reporting in the developing world is hampered by a fundamental shortage of manpower in both the human and animal health sectors, the vast distances that are often involved, poor transportation infrastructure, insecurity, which prevents access to some regions, and open porous borders which allow free movements of people and animals. The chronic lack of response (or capacity to respond) to reports of disease is further disempowering and de-motivating for healthcare and veterinary workers at the grass roots level.

The factors described above relate mostly to an inability to detect disease and report on its presence, but there are also a number of influences that reduce the willingness of animal owners and health workers to detect and report disease on the ground. Collecting animal samples for surveillance can be extremely arduous, hazardous and unpleasant (e.g. post-mortem sampling), reducing the likelihood that this will happen in the absence of appropriate incentives. Amongst animal owners and animal health workers social barriers to reporting also operate as individuals may be unwilling to report illness and initiate a process of investigation and response that may have severe social and economic implications for both themselves and their neighbours (IOM and NRC, 2009; The World Bank, 2010). The economic implications of reporting disease outbreaks are discussed further in Chapter 5.

The broad range of factors that influence the reporting of zoonoses are themselves a reflection of the multiple impacts of zoonoses and the degree to which livestock animals are an integral part of many peoples lives, in the developing world especially. The human populations that are dependent upon livestock are often vulnerable to many different zoonoses, which can have compound impacts upon animal health and productivity, human health and productivity, livelihoods and social status. Because of these multiple impacts, the implications of reporting disease can also be very complex.

Overall, in the absence of a sufficiently large population of trained observers and deficiencies in systems for the feedback of information or provision of assistance in response to a reported problem, it is not hard to see why disease detection and reporting is often so inadequate. Options for improving these processes of detection and reporting can be broadly categorised as 'carrots', measures devised to positively incentivise reporting and 'sticks', which are implemented to punish failure to comply with pre-existing standards. For most if not all countries, there are regulations that describe legal requirements for members of both the animal and human health sectors to alert the relevant authorities as and when they become aware of a number of notifiable diseases, but under-reporting still persists.

Across much of the developing world, at the local level particularly, the data and infrastructures required to enforce the use of punitive measures such as legally required reporting are just not available (The World Bank, 2010). In order to punish non-reporting amongst farmers or under-performing vets for example, accurate data would be required on who owns which animals where and prior knowledge of baseline disease presence. There also needs to be a much higher likelihood than currently exists that disease cases would be detected without the cooperation of the local community. Given that these requirements are not in place in many cases, attempts to impose sanctions for non-reporting on the local scale are unlikely to succeed and will instead act to further damage relations between animal owners and the systems that it would be desirable for them to interact with. Instead, a more positive focus should promote the value of reporting, celebrate small successes and reward change. In order to foster cooperation at all levels in a reporting system, the deterrents to reporting must be at least balanced with positive incentives (The World Bank, 2010). For individual farmers these incentives may include eligibility for quality certification schemes to promote regular status determination and reporting or compensation schemes in the event of an outbreak in which livestock are compulsorily slaughtered. Following the international spread of H5N1, guidelines for compensation payments in response to compulsory slaughter campaigns were agreed in December 2006 (The World Bank, 2010). In any particular outbreak though, the relative value of financial compensation offered will be considered alongside the commercial value of an animal as well as a range of other potential benefits and costs associated with reporting disease presence. Care must therefore be taken to ensure that any financial compensation provided is tailored to local situations and is sufficient to tip the overall balance in favour of reporting but not large enough to encourage import of healthy animals to outbreak affected areas in order to obtain compensation (The World Bank, 2010).

Whilst feasible in some richer countries, the use of compensation schemes may prove challenging in more resource limited settings. In order to provide timely compensation a pre-existing record of animal ownership is required and funds must be readily available to cover the costs of compensation. The creation of a global fund that would finance global outbreak response efforts has been proposed to ensure that such funds would be available, even when outbreaks occur in countries unable to directly finance compensation schemes (The World Bank, 2010).

There is also a need to consider whether incentives should be provided to those responsible for reporting of diseases and other relevant information. If this approach is sanctioned, a decision will also need to be taken as to what incentives can be provided to staff responsible for the collation and analysis of these data. When the required data resides largely in another sector e.g. disease information held by private veterinarians, the incentives offered must be commensurate with the time and effort involved in making that information available to the public sector reporting system. In some cases the answer may lie simply in financial arrangement, but in other cases a trade-off of "reporting for information" might provide an alternative approach. The current initiative of the Kenya Veterinary Board requiring Continuing Professional Development (CPD) might offer a means by which CPD points could be earned in return for undertaking a CPD reporting module with a requirement to submit a given number of reports per month or train other staff to do so.

Previous efforts to enhance disease detection have focused largely upon technical innovations (The World Bank, 2010). The development of quick and simple diagnostic tools is clearly of value in resolving this detection problem but particularly when there may be a range of other factors that act as barriers to reporting, improving the ability to detect pathogens does not on its own lead automatically to an increased likelihood of reporting (Laxminarayan and Malani, 2009). In addition to developing and providing tools for disease detection and reporting, there is also a clear need to better understand why individuals do/do not choose to act at different points in a reporting network in order to design effective enhancements to surveillance systems.

While incentives often focus on tangible financial benefits, the greatest incentive may be the provision of simple responses, including acknowledgement of a report, feedback of diagnostic test results, and advice on management of the disease problem. The success of telephone 'hotlines' in Denmark is testament to this approach. The scheme, which was primarily set up to provide diagnostic support for livestock veterinarians, has proved to be an effective tool for detecting new diseases (Hoinville et al., 2009). With the widespread use of mobile phones across the developing world (See Section 6.5.2), these measures could provide a simple starting point for improved communication between livestock-keepers, field staff and central veterinary authorities.

5.3 Institutional structures & interactions

Surveillance is ultimately a matter of communication between stakeholders and the reporting of zoonotic diseases is negatively affected by the separation that exists between human and animal health disciplines. The persistence of institutional separation can create barriers to communication between the human and animal health sectors, leading to delays in reporting and in the implementation of responses. Such failures are for example believed to have contributed to delays in recognition and response to a number of recent disease outbreaks of significance including WNV in 1999, monkeypox, H5N1 HPAI in 2003 and Ebola in 2001-2003 (IOM and NRC, 2009).

A practical examination of communication between these sectors has been conducted at the state level in the United States (Scotch et al., 2010). Individuals from the two sectors were found to communicate frequently but respondents also identified both technological barriers and issues of data sensitivity and trust as ongoing challenges to further integration (Scotch et al., 2010). This study again illustrates the need to address both the practical elements of communications technology as well as the human element. Individuals in both sectors need to collaborate and trust one another to handle sensitive data. To foster this collaboration and the mutual respect required for sustained interaction, it is proposed that specific meetings and workshops should be held to bring these groups together and enable them to collaborate in the design of integrated systems and engender a sense of cooperation and co-dependence from the outset (IOM and NRC, 2009).

Within veterinary sectors and increasingly also within medical sectors, reporting networks can also be adversely influenced by the separation between private and public sectors and service providers. In Kenya for example, the policy framework enables private animal health service providers (PAHSPs) to deliver private good clinical services whilst the district veterinary officer (DVO) is responsible for regulatory and quality control functions. This division often results in the DVO being one step removed from the livestock keepers and reliant on the PAHSP for information on any disease outbreak events. There can be significant barriers to this information flow, particularly when relationships between the DVO and the PAHSP are strained by the lack of sanitary mandates, service provision disputes often relating to poorly applied legislative frameworks and the lack of recognition of frontline personnel by the higher public sector authorities.

In terms of less tangible social institutions, it is likely that different social groups and indeed individuals with diverse social roles will have different perspectives and approaches to disease reporting. As a consequence, it is likely that the barriers and therefore also the incentives required to overcome them may vary for different individuals and social groups. Considerable research is therefore required to investigate the influence of social parameters including gender, age, ethnicity, socioeconomic status, religion and broader social context upon disease reporting practices and upon the interaction of different groups within the reporting pyramid.

5.4 International reporting regulations

There are no dedicated reporting systems that govern zoonoses reporting at the international level. Instead, zoonoses are partially covered by separate sets of regulations and requirements for the animal and human sectors. In the human health sector, the International Health Regulations (IHR) provide a legislative framework that formalises the human disease reporting responsibilities of national governments. The recently revised IHR (IHR 2005) set minimum requirements for developing and maintaining core capacities for detecting and responding to emerging threats and are accompanied by a decision-support tool designed to help in the identification of public health emergencies of international concern (PHEIC). Participating countries are required to report a PHEIC occurring within their territory to the WHO within 24 hours of its identification and that country could then receive assistance in responding to that PHEIC from WHO and the GOARN (Nicoll et al., 2005; Merianos and Peiris, 2005; Hitchcock et al., 2007; The World Bank, 2010). Despite the inclusion of mandatory requirements for improvements to national level surveillance capacities, it is not clear what if any additional funds are available to enable governments to meet these required standards (Nicoll et al., 2005), or what sanctions will be imposed in the case of failure to meet these requirements or delayed reporting (The World Bank, 2010). Regarding surveillance of zoonoses specifically, the example health events covered in the revised IHR include only a select few zoonotic pathogens that are considered high-profile international emerging threats (e.g. viral haemorrhagic fevers, WNV and HPAI) and the guidelines include little reference to endemic zoonoses or to integrated surveillance of animal and human populations. The revised IHR therefore only apply to the detection and reporting of zoonoses in the event of an outbreak of illness in humans that is considered to be of international concern.

In the animal sector, the closest equivalent to the IHR is the Terrestrial Animal Health Code of the OIE, which requires veterinary services in participating states to carry out monitoring, surveillance and reporting of animal disease outbreaks, particularly outbreaks of listed notifiable diseases to the OIE. The OIE PVS tool is designed to enable evaluation of the capacity of veterinary services to meet these requirements but although there are reports of a positive influence of the PVS systems upon reporting

(The World Bank, 2010), the PVS assessments are voluntary guidelines only and the OIE has no capacity to respond to an outbreak without official notification from a member state.

These regulations are designed to encourage reporting of disease outbreaks to the international community but they do little to address the significant barriers that act as strong disincentives for a country to report a disease outbreak. Principal amongst these are the economic and social consequences of reporting outbreaks. In the human health sector, there are well described cases in which the occurrence and reporting of disease outbreaks in developing countries has led to overreaction within the international community resulting in long-term negative economic and social consequences in terms of imposition of trade embargoes, loss of income from tourism and overall impact upon international reputation (Cash and Narasimhan, 2000). In the animal sector, the regulations governing disease reporting and response are very heavily influenced by economic and trade considerations (Merianos and Peiris, 2005) because of the enormous impacts that disease reports can have upon national economies.

It can be hard to quantify the direct and indirect economic losses associated with zoonotic disease outbreaks specifically, but the existing estimates illustrate the scale of impact that these outbreaks can have. CDC estimates reported by the World Bank (2010), for the direct costs of recent zoonoses outbreaks include $400 million for Nipah virus in Malaysia. $11,000 million for BSE in the UK, and $50-120,000 million for SARS globally (The World Bank, 2010). Because of the potentially enormous scale of these economic consequences of disease reporting, the OIE PVS tool emphasises the importance of the independence of veterinary services from more commercially oriented government departments when it comes to disease reporting and their is some evidence that the use of the PVS tool and promotion of sectoral independence has contributed to a reduction in under-reporting at this institutional level (The World Bank, 2010).

5.5 Regulations & rumours

In recognition of this strong disincentive for national governments to report disease outbreaks, the revised IHR now include new authorisation for WHO to initiate a response to a PHEIC without official notification from the nation state in which that PHEIC is detected (Merianos and Peiris, 2005; IOM and NRC, 2009). The OIE currently has no equivalent authority to act upon 'rumours' and instead must ask national veterinary system representatives to provide verification of unofficial reports of animal disease. However, the overall response rate to requests made by the OIE in the period 2002-2007 was only 70% (IOM and NRC, 2009; The World Bank, 2010) and it has been argued that the OIE reporting regulation should also be revised to obligate nations to respond to these rumours and allow international action (IOM and NRC, 2009; The World Bank, 2010). This move towards the use of rumours is driven in large part by the concerns of the international community regarding novel emerging threats and enabled by the recent advances in the internet-based technologies that bring outbreaks to the attention of the international community in the absence of official notification (See Section 6.5.1 for further discussion of these novel approaches). This new approach has several potential consequences for global disease reporting practices. As it becomes increasingly unlikely that governments will be able to conceal disease outbreaks, it is argued that governments will effectively be pressured towards policies of greater transparency and compliance (Cash and Narasimhan, 2000; Chan et al., 2010). However, it can also be argued that given the potential for rumours emanating from a country to have such severe negative impacts, and in the absence of any coherent mechanism for compensating against these impacts, governments may effectively have nothing to lose and everything to gain by inhibiting reporting. In this context it is therefore understandable that some institutions may be encouraged to try to suppress negative disease-related news events.

The fact that the majority of recent confirmed outbreak investigations conducted by WHO were prompted initially by unofficial reports (Chan et al., 2010), indicates that rumours already act as an important supplementary reporting channel (Laxminarayan and Malani, 2009). However, over-reliance upon rumour-based reporting has other negative consequences. Rumours do not provide the detailed epidemiological information required to respond as efficiently as possible in an outbreak situation (IOM and NRC, 2009) and reliance upon them introduces considerable risk of false-positives and the incorrect imposition of potentially severe economic sanctions. Following this approach is also unlikely to enhance countries' incentives to look for and report outbreaks (Laxminarayan and Malani, 2009). It is therefore conceivable that whilst failing to tackle the underlying reasons for poor detection and reporting capacity this recent focus upon rumour-based reporting systems will have disproportionate negative impacts upon developing country nations. In combination with the revised IHR, these systems are likely to lead to increased application of harsh sanctions upon the detection of disease outbreaks and countries with under-developed infrastructure are particularly vulnerable in this situation. These countries are most susceptible to disease outbreaks (Chan et al., 2010), have less capacity to detect or report them and are also the least able to withstand the harsh socioeconomic consequences when sanctions are imposed (Cash and Narasimhan, 2000). There is the risk therefore of perpetuating a lack of transparency and trust within the global reporting system whilst simultaneously failing to make any progress towards enhancing the rapid identification of outbreaks on the ground.

5.6 Incentivising reporting

Effective surveillance systems rely on observer and institutional willingness and ability to accurately and rapidly report disease outbreaks, at both local and national levels. This willingness is in turn dependent upon the capability to implement local, national and international responses and any lack of capacity to respond to a detected threat can dampen enthusiasm for timely and comprehensive reporting. Ultimately, the greater the return for reporting an outbreak or case, the greater the return for detecting it in the first place (Laxminarayan and Malani, 2009). Barriers to reporting need to be recognised and tackled, by for example, designing enhanced global regulations that prevent the over-reaction of the international community to disease reports. At present, the scale of sanctions that a reporting country faces can be enormously inflated and this system of sanctions is likely to work better, to have greater validity and to encourage earlier reporting if sanctions are proportional to the size of the outbreak at the time of reporting (Laxminarayan and Malani, 2009). In addition, it is crucial to understand how to positively incentivise reporting in order to achieve improvements in detection. The appropriate benefits associated with participation in surveillance activities will vary according to the different stakeholders involved but may include meeting performance contracts, remuneration, capacity building, event information, resourcing, career advancement or reinforcement of social standing (such as by triggering an effective response). At the global scale, the establishment of a global fund to financially compensate countries that report outbreaks and the provision of more useful medical assistance at the time of outbreak reporting have been proposed (Laxminarayan and Malani, 2009; The World Bank, 2010). Countries are more likely to invest in surveillance for diseases they can control (Laxminarayan and Malani, 2009) and surveillance and response systems based around an intervention that is useful for the community in the immediate future can therefore provide the basis for the addition of other elements and development of more generic longer term capacities.

The developing world has been identified as a weak spot in current surveillance capacity and these are also the communities in which the neglected endemic zoonoses impose the greatest burdens. The endemic zoonoses have been described as 'low hanging fruit' for control and elimination (Molyneux, 2008). The tools to tackle these disease threats exist but the required investment has been lacking. With the current focus upon how to conduct surveillance for emerging pathogens there is an opportunity to effectively use these 'low hanging fruit' to tackle the burden of endemic zoonoses in its own right whilst simultaneously using this effort to demonstrate the importance of effective responses in incentivising surveillance and to engender a culture of surveillance in those areas of the world where it is most needed (The World Bank, 2010).

5.7 Discussion

Effective surveillance is only feasible if individuals want to contribute and in some cases, under-investments in surveillance systems arise because it can be better in both economic and social terms not to know about a problem, than to know about it but not be able to do anything to resolve it (Laxminarayan and Malani, 2009; The World Bank, 2010). In the developing world particularly, the current regulatory frameworks and potentially catastrophic economic costs associated with reporting a disease outbreak do little to encourage investment in effective disease detection and reporting on the ground. On the international scale, the countries with less developed surveillance infrastructure are most likely to suffer disease outbreaks (Chan et al., 2010), least likely to have validity on the international stage in terms of trust and confidence in official reporting mechanisms and are also most likely to be severely affected by economically damaging international responses based on either reports or rumours. As a consequence, these are currently also the countries that are least likely to invest in surveillance (Cash and Narasimhan, 2000; Laxminarayan and Malani, 2009).

There therefore exists the potential at least for tensions between the surveillance needs and motivations of the international community concerned principally at the global level with the detection or emerging diseases and developing country nations for which endemic zoonotic pathogens may pose greater threat and for which there are few if any resources available for either surveillance or response. In order to reconcile these differences and motivate reporting where it is currently least effective, it is necessary to recognise that additional funds will be required to achieve the improvements in national capacity requested by the international community and that this system should be designed in such a way that it 'works' for the developing country nations themselves and meets their needs as well as those of the wider global community. If not, it is very unlikely that an effective system of reporting will be created. Bioeconomic modelling indicates that enhancing a country's capacity for outbreak control will result in greater investment in surveillance more generally (Laxminarayan and Malani, 2009) and future research effort should therefore be focused at breaking the feedback cycle that perpetuates the circumstances where the weakest disease surveillance capacity coincides with greatest zoonotic disease burden. To do this, it is important to start by focusing upon providing effective response to existing zoonoses. It is too often the case that surveillance and response activities are not as well integrated as they should be and the failure to maintain response capacity will inevitably lead to the neglect of surveillance capacity. In this model, the initial focus is on enhancing response measures targeted at existing zoonotic pathogens and surveillance is the tool used to ensure that resources for response can be most effectively targeted.

There is also a need to re-focus at the bottom of the reporting pyramid as this is the fundamental source of all surveillance data and the surveillance of both endemic and emerging pathogens is dependent upon the timely collection of accurate and comprehensive 'on the ground' field data. By focusing on endemic rather than emerging pathogens, investment in responses can yield tangible rather than potential benefits and provide demonstrable incentives to encourage ongoing reporting and contribute to an appreciation of the value of linked surveillance and response. This strategy could therefore have the multiple benefits of i) encouraging investment in the control of previously neglected endemic zoonoses which impose considerable socioeconomic burdens in developing countries (Maudlin et al., 2009) and ii) demonstrating the value of good reporting, surveillance and response in those parts of the world where surveillance capacity is currently weakest. This approach could contribute to the creation of a culture of surveillance that would enhance both local and global disease surveillance and response capabilities.

5.8 Conclusions

There are multiple factors that contribute to the under-reporting of disease in general and zoonoses, particularly in developing countries. Previous efforts to enhance reporting have often concentrated on individual barriers in isolation rather than attempting to understand the complex interaction of factors that lead to persistent under-reporting (The World Bank, 2010). In recent years, there has been a focus on the technological barriers to reporting and into improving the speed of information flow from the national to international level. We argue that future attempts to enhance the reporting of disease in developing countries should be built upon much greater understanding of why individuals choose to act and to report disease, rather than focusing exclusively on the practical tools used.

This report has identified several barriers to reporting and capacity gaps that operate to reduce disease reporting at different levels in developing countries:

- low clinical awareness of zoonoses and poor availability of reliable diagnostic tests;

- animal-owner familiarity with the presence of zoonotic pathogens and acceptance of this as the 'normal' condition;
- fundamental shortage of resources for disease detection and reporting in both the human and animal sectors - including funds, personnel and infrastructure;
- separation between the animal and human health sectors and barriers to communications, which contribute to delays in the reporting of zoonoses particularly;
- lack of a clear regulatory system governing the reporting of zoonoses - neither the WHO IHR or OIE Terrestrial Animal Health Code provide clear guidelines on the reporting requirements for both emerging and endemic zoonoses.

These gaps in capacity contribute to multiple disincentives identified for reporting including:

- the arduous and sometimes unpleasant nature of field diagnostic sample collection and follow-up;
- reluctance to initiate a process that may lead to severe consequences for the livelihood of the reporter directly or other community members;
- the probable absence of any feedback or useful response to reports made;
- long term negative economic and social consequences of disease reporting at the national level, including trade embargoes and loss of income from tourism.

To tackle these gaps and reporting barriers, future research activities must prioritise the incentivisation of reporting. In the developing world particularly, the use of incentives is much more likely to be effective than punishment of non-reporting and the reliance upon rumour-derived information. Overall, there is a need to focus on understanding what motivates reporting. Providing the technical means of detecting disease is not sufficient for the data to be generated and reported and there is a need to better define what other inputs can be provided to ensure this. Specifically, future research effort should focus on:

- social science investigations conducted to generate better understanding of the barriers and motivations important for different stakeholders and reveal when and why different members of a reporting network do/do not act to report disease information - these should focus ideally upon existing developing country zoonosis reporting systems;
- identifying and field testing different options for locally appropriate reporting incentives - options may include performance-based contract schemes, direct remuneration, capacity building, basic feedback and information provision, CPD, career advancement and also enhancement of social standing depending on the stakeholders involved;
- encouraging the involvement of representatives of the human and animal health sectors throughout the process of surveillance system design and implementation to encourage the collaboration and mutual respect essential for sustainable interaction and effective surveillance.

In addition, a number of changes in international policy could be made to enhance global disease reporting networks. These would include:

- the development of zoonosis-specific reporting guidelines to define 'best practice' in the national reporting of zoonosis surveillance data (concerning both endemic and emerging diseases) to the international community - this would be most appropriate if developed through the existing collaboration between WHO, OIE and FAO
- the development of an international fund and taskforce to provide greater assistance to nations that report disease outbreaks to the international community (the nature of the assistance provided should be informed by the social science research activities advocated above)
- the creation of an international regulator that has greater powers to penalise and prevent over-reaction by non-reporting nations in terms of trade embargoes and guidance to tourists as and when nations do make disease reports to the

international community and to provide compensation for reporting countries as and when this happens

- continued advocacy for the separation and independence of veterinary public health and commercially oriented government departments to reduce the influence of commercial and economic factors upon surveillance activities and reporting

Chapter 6

Innovative methods for zoonotic disease surveillance

6.1 Summary

Many of the challenges associated with zoonotic disease surveillance are particularly acute in developing countries. Whilst posing considerable challenges, the limited infrastructure and availability of resources in these contexts have also stimulated a range of innovative approaches that may provide opportunities for improved efficiency of surveillance, not only in developing countries but also in more industrialised countries. Here, we review the existing literature on innovative methods for zoonotic disease surveillance, including both approaches to surveillance overall and also tools that can be employed within surveillance systems. Syndromic surveillance, the use of sentinel or proxy animal populations and risk-based techniques have all been proposed as flexible and relatively inexpensive approaches for timely collection of surveillance data over broad geographic scales. There is also a growing literature on electronic data capture and transmission methods, which have been developed as a means of reducing errors and allowing real-time access to data. Whilst all of these approaches have the potential to achieve timely data collection, and to enable access and greater use of less traditional data sources there are also concerns about the validity of the data generated through some of these

techniques. It is important to recognise that these approaches are proposed as complementary tools rather than alternatives to more classical epidemiological work and good surveillance system design. As is the case with any surveillance tool, their utility needs to be evaluated on a case-by-case basis and it is likely that the utility of these new approaches may be greatest in areas that are currently least well served by existing surveillance systems. The increasing accessibility of mobile phone technology, for example, creates exciting opportunities for disease surveillance and response. The use of mobile phones provides the capacity for two-way exchange of information and may therefore have particular advantages for zoonotic disease surveillance where communication between different stakeholders can be limited and where there is a clear need to develop tools that help to address existing capacity gaps in rural livestock-owning communities. Similarly, syndromic surveillance, sentinel surveillance and participatory epidemiology are all flexible tools that may have great value in describing the current distribution and burden of zoonotic diseases and tackling the current lack of baseline data on disease distribution that is essential to inform efforts to target research at current zoonoses hotspots.

6.2 Syndromic surveillance

Syndromic surveillance refers to the use of clinical or health-related information that precedes definitive diagnosis of specific disease conditions (Henning, 2004). In contrast to more traditional surveillance systems which rely on the establishment of a diagnosis, usually through laboratory testing of submitted clinical specimens, syndromic surveillance systems make use of pre-diagnostic data to enable more rapid detection of disease outbreaks. Although some authors include the use of proxy health-related information under the heading of syndromic surveillance (e.g. absenteeism or over-the-counter medicines sales; Henning (2004)), more recent usage in the public health literature confines the phrase to the description of surveillance systems that use patient clinical data captured at health care facilities at the time of presentation and/or discharge to identify outbreaks in the catchment population. Clinical signs, symptoms, and possibly other abnormalities indicative of a diseased state and detected at the time of presentation (e.g. bed-side test results), are grouped into syndromes, according to the objectives of the surveillance system. Clinical signs and other abnormalities may thus be assigned to a syndrome on the basis of a common organ system (e.g. respiratory tract diseases), common clinical presentation (e.g. severe acute respiratory illness), or a common putative cause (e.g. influenza-like illness). The primary goal of syndromic surveillance, namely, timely detection of outbreaks, may be achieved only through a reduction in the specificity of case definitions when compared to traditional surveillance systems; however, further research may be needed to identify effects of case definitions on the sensitivity and specificity of syndromic surveillance systems (e.g. Guasticchi et al. (2009), and to determine the optimal combination of timeliness, sensitivity and specificity for particular programmes. Ideally, a syndrome will have a high probability of association with a given target disease, analogous to a diagnostic test with high predictive value of a positive result. This is the case for example with the use of acute flaccid paralysis syndrome in poliomyelitis surveillance (Robertson et al., 1994) but just as positive predictive value of a positive result in a diagnostic test is dependent upon disease prevalence, the accuracy of different pre-diagnostic syndromes can also vary. For example, during influenza seasons, reporting of influenza-like-illness (ILI - defined as fever and cough or difficulty breathing) can successfully predict influenza infection in as many as 79% of adults and 83% of children (Ohmit and Monto, 2006). However, when applied over longer periods the predictive value of ILI can be lower (Ohmit and Monto, 2006) and these symptoms can also be caused by a large number of other pathogens including malaria and a range of other respiratory viruses (Monto, 2002). In other contexts, syndromic surveillance can be employed to detect new, emerging diseases, by selecting non-specific syndromes, such as acute febrile or respiratory illness, that will impart a high sensitivity.

Although deployment of syndromic surveillance is widespread in human public health systems (e.g. Lewis et al. (2002); Irvin et al. (2003); Loonsk (2004)), few examples can be found in the veterinary field. Vourc'h et al. (2006) describe three syndromic surveillance systems in farm animals: the Veterinary Practitioner-Aided Disease Surveillance System (VetPAD; New Zealand), the Rapid Syndrome Validation Project Animal (RSVP-A; U.S.A), and the 'émergences' system (France). The VetPAD system provides a platform for private veterinary practitioners to capture and categorise clinical diagnoses, by integrating data capture into a broader practice management system using hand-held personal digital assistants (PDAs, or 'pocket PCs'). The RSVP-A system relies on reports made by private veterinarians who determine if cases of disease in cattle fit any of the specified syndromes of interest (non-neonatal diarrhoea, neurological dysfunction or recumbency, abortion or birth defect, unexpected death, erosive or ulcerative lesions, and unexplained feed refusal or weight loss). The 'émergences' system is designed to detect new or unknown diseases, or atypical cases of apparently known diseases, and relies on a free-text clinical description of the case, submitted by the veterinarian using a web-based form. Cases may then be categorised by the system administrator on the basis of the clinical descriptions.

Shephard (2006) describes the development of a web-based reporting system for cattle diseases in the extensive cattle producing regions in northern Australia. Known as the Bovine Syndromic Surveillance System (BOSSS), it uses a novel graphical user interface linked with an interrogation module to allow observers (stockmen) to accurately and fully describe the disease. The system incorporates a Bayesian cattle disease diagnostic programme, which provides the observer with immediate feedback based on their clinical observations, including a list of differential diagnoses, further questions that may help further differentiate cause, and access to information and other expertise. Metre et al. (2009) describe a syndromic surveillance system based on visual inspection for the detection of disease in livestock entering auction markets, and propose 12 syndromes based on clinical signs observed during deployment of the system in a single large auction market in Colorado.

The above systems focus on surveillance for emerging and transboundary diseases of livestock, and cattle in particular. By contrast, the National Companion Animal Surveillance Program (NCASP) established at the Purdue University School of Veterinary Medicine, U.S.A., collects medical records from small animal pets attending any of the more than 500 hospitals of a private animal health care provider, Banfield (Glickman et al., 2006). Although the system captures clinical data from approximately 3 million cases per year, its primary purpose is a resource database for further epidemiological research on the role of companion animals in the emergence of zoonoses, and not specifically for syndromic surveillance (Burns, 2006). This illustrates a key point: if the stated goal of syndromic surveillance is the early detection of disease anomalies to allow prompt action, data must be analysed routinely, and follow-up processes defined. A key component of effective syndromic surveillance systems is the use of statistical algorithms to detect when the occurrence of a particular syndrome exceeds expected levels for a given geographic location and time (ideally taking into account temporal trends in disease reports, real or artifactual). Timely detection of anomalies is improved through the routine, automated application of these algorithms, and visual display of results. As a prerequisite, baseline rates of defined disease syndromes must first be established and thresholds determined which, if exceeded, will trigger further action. The nature of such action (e.g. further epidemiologic or diagnostic investigation) should also be predefined.

Despite early calls to integrate surveillance in human and animal populations for targeted infections, e.g. zoonotic and emerging diseases (Shears, 2000), few such systems are found in the literature. Rockx et al. (2006) describe a surveillance system in the Netherlands for the early detection of West Nile virus epidemics. The system includes surveillance based on human hospital discharge diagnoses, cerebrospinal fluid (CSF) diagnostic requests, laboratory CSF test results, and monitoring of neurological disease in horses, and thus represents a combination of syndromic surveillance in humans and horses, indicator/proxy surveillance (CSF diagnostic requests) and traditional, laboratory-based surveillance. Babin (2010) proposes the inclusion of syndromic surveillance of particular animal species (cats, chipmunks) in an integrated syndromic surveillance system for early detection of pneumonic plague, but does not go on to suggest how such a system might be established or integrated.

The results of this brief review have shown that, despite the widespread adoption of syndromic surveillance in human public health systems for the early detection of disease outbreaks, and the clear need for such systems in the veterinary sector for the early detection of transboundary, emerging and/or zoonotic diseases, few syndromic surveillance systems are in routine use in animal populations, and none in developing countries. Several obstacles to their widespread adoption in the veterinary sector can be identified. Firstly, systematic capture of patient clinical information is rarely undertaken, and particularly not in a format conducive to rapid onward transmission and analysis. To be sustainable, surveillance systems should incorporate electronic capture of clinical data into systems that facilitate routine practice management (e.g. Vet-PAD) or provide diagnostic support (e.g. BOSSS). Secondly, no standard exists for the classification of clinical information into disease codes that might facilitate comparison and automated analysis of data from different practices or regions. The International Classification of Diseases, Ninth Revision (ICD-9) provides such a standard in human public health surveillance (see, for example, Marsden-Haug et al. (2007)). Thirdly, early detection of disease anomalies presupposes the existence of baseline data on the incidence of clinical syndromes of interest. Other surveillance challenges are not unique to syndrome-based systems: the need for routine analysis of data and application of anomaly-detection algorithms, and the implementation of a response plan should such anomalies be detected. In developing countries in particular, the lack of both animal health professionals on the ground, and resources to provide preventative or curative treatment for diseased animals and poor communication between animal health workers and animal owners are additional challenges.

To be effective, syndromic surveillance systems should benefit not only those tasked with early detection and control of outbreaks, but also those called on to capture and transmit the data. In developing countries, where this would be the responsibility primarily of animal health technicians or paraveterinarians who may have little training in the differentiation and treatment of animal infectious diseases, the BOSSS model offers one potential solution. This system combines the capture of clinical data (for surveillance purposes) with a diagnostic decision-support tool that uses the captured data to offer differential diagnoses with relative probabilities, along with advice on further investigations and treatment options. Animal owners may also perceive the benefit of improved animal health service provision, and thus be more likely to sustain the system though ongoing reporting of cases.

6.3 Animal sentinel surveillance

Sentinel surveillance is a form of surveillance in which activities focus on specific sub-populations to enhance detection of disease and/or improve the cost-effectiveness of surveillance (McCluskey, 2003). The data generated through observation of the sentinel population can then be used to infer the risks posed to the larger population. The use of animal sentinels for detecting biochemical threats is well established (e.g. the coal miners canary, and see Rabinowitz et al. (2005)) but despite the surveillance opportunities provided by the multi-host capacities of many zoonoses, the application of animal sentinels for the surveillance of zoonotic pathogens is less well described (Rabinowitz et al., 2005; Halliday et al., 2007; Rabinowitz et al., 2008).

Animal sentinels can and have been used to address a wide range of surveillance questions including the detection of a pathogen in a new area, the detection of changes in the prevalence or incidence of a pathogen/disease over time, determining the rates and direction of pathogen spread, testing specific hypotheses about the ecology of a pathogen and evaluating the efficacy of potential disease control interventions (McCluskey, 2003; Halliday et al., 2007; Yale Occupational and Environmental Medicine Program, 2010). The desirable attributes of a sentinel population vary by surveillance purpose and also context. There is no universally appropriate sentinel population and in different contexts and settings, different animal populations will vary in their capacity to provide useful surveillance data. Factors including the relationship between the sentinel and target populations, the transmission route(s) of the pathogen to the sentinel and target populations and the nature of the sentinel response to the pathogen all influence the potential utility of different animal populations to act as sentinels of pathogen presence in different contexts (Halliday et al., 2007).

In the developing world context, where the current state of infrastructure severely limits surveillance capacity, there is a considerable lack of baseline data on which pathogens pose a threat and sentinel surveillance approaches may provide a comprehensive yet flexible and cost-effective tool for addressing these fundamental knowledge deficiencies (Halliday, 2010; Lembo et al., 2011). Carnivores and specifically domestic dogs have a number of attributes that may make then suitable sentinels for a range of zoonotic pathogens, and of particular value as animal sentinels in developing country contexts (Cleaveland et al., 2006). There is considerable evidence that carnivores can be exposed to a range of pathogens including emerging zoonoses such as influenza A and WNV through the consumption of infected material (Murray et al., 1999; Austgen et al., 2004; Thiry et al., 2007; Giese et al., 2008) and that a bio-accumulation effect, whereby predators and scavengers effectively sample from prey populations, can lead to the accumulation of the pathogen itself or of evidence of exposure within carnivore populations so that pathogen presence may be detected relatively inexpensively and cheaply by sampling a small number of carnivores (Cleaveland et al., 2006). Domestic dogs are widely distributed and essentially ubiquitous within human communities throughout the world, they live in close proximity to people and are readily accessible for handling and sampling (Cleaveland et al., 2006; Halliday, 2010). Particularly when combined with rabies vaccination campaigns, it is therefore possible to rapidly conduct cost-effective serosurveillance of domestic dogs at the village level over a large area for example an entire region, and to generate a broad-strokes picture of which pathogens are present where (Cleaveland et al. (2006), e.g. for Ebola in Gabon, Allela et al. (2005) and for Anthrax in Northern Tanzania, Lembo et al. (2011)).

Surveillance of sentinel populations that are both exposed to the pathogen of interest and which respond to the presence of that pathogen prior to the exposure of the target population can provide timely 'early warning' data that can be used to prioritise additional surveillance resources, implement control measures and potentially prevent the exposure of the target population altogether. In cases where animal sentinels have been used to provide a warning of a zoonotic threat to human health it is often the case that the response of the sentinel to the pathogen is dramatic and highly visible, such as widespread mortality, e.g. corvid deaths associated with the spread of West Nile Virus (WNV) in North America. The data provided by these kinds of dramatic signals can be processed, analysed and acted upon rapidly, often without the need for time-consuming sample collection and diagnostic testing. In such cases the response of the early warning sentinel to the presence of the pathogen should also be very specific, to minimise the risks of false-positive reports and to enable improved confidence in decision-making based only on the sentinel response only (Halliday et al., 2007). For this reason however, there are in fact only a relatively small number of examples of this kind of dramatic but well characterised and specific signal and in most cases, sample collection and diagnostic testing are required to detect and interpret the signals provided by animal sentinel populations.

As with all other forms of surveillance, the potential value of data generated from animal sentinels can only be realised if the information gathered is distributed in a timely way, to enable prompt action. Despite increasing recognition of the potential value of animal sentinels for zoonosis surveillance there are many examples of situations in which disease outbreaks that have affected both animals and humans (often with the first cases observed in animals) have only been widely reported and recognised once human cases occur (e.g. few pre-emptive measures taken despite primate deaths caused by Ebola prior to human cases, (Rouquet et al., 2005), RVF consistent mortality recognised by pastoralists well in advance of public health responses in Tanzania and Kenya, (Jost et al., 2010)). It is argued that such failures to fully utilise data from animal sentinels stems from a basic lack of integration between the veterinary and medical disciplines and from the perpetuation of an 'us vs them' paradigm in which animals are viewed as the potential source of human diseases rather than a key to understanding shared risks (Rabinowitz et al., 2008). However, it is also the case that hindsight simplifies the interpretation of these data and that the setting of surveillance has a considerable influence upon the interpretation of the findings of sentinel surveillance. First, there is a requirement for a network of observers who can observe and report any signals observed in a sentinel population. In North America for example, the capacity of dead crow density measures to forecast human infections with WNV was reduced in rural as compared to urban areas because of reduced detection and reporting rates (Eidson et al., 2005; Ward et al., 2006). Secondly, where a network of observers does exist, in order to detect for example, unusual die-offs in an animal population and for this to be interpreted as a potential signal of zoonotic pathogen presence and human risk, a comprehensive understanding of normal patterns of morbidity and mortality in animal populations is needed and such data are often scarce, particularly for wildlife populations.

The science of surveillance using animal sentinels is relatively under-developed and numerous factors including the lack of integration between human and animal medicine and a lack of quantitative methods for linking animal and human health data have contributed to this (Rabinowitz et al., 2005, 2008; Scotch et al., 2009). However, animal sentinels do offer a clear opportunity to address some of the deficits that are currently faced in the field of zoonosis surveillance. Rather than providing precise estimates of disease incidence or prevalence, the aim of sentinel surveillance is to provide timely and relatively inexpensive information (CDC, 2008) that may have relatively limited resolution or accuracy. The nature of sentinel surveillance is that the sentinel population is used as a proxy for the population of interest and that data generated is gathered at a step removed from that population. Uncertainty about the 'true' picture of pathogen presence in the target population is inevitably introduced through this process and as a consequence sentinel surveillance is best suited to surveillance of broad scale patterns of pathogen presence rather than to more refined surveillance/epidemiological questions for which a higher degree of precision is required. In many parts of the world, the basic surveillance questions of what pathogens are present in which populations remain unanswered and as a consequence the global community has very limited data upon which to base assessments of risk. Sentinel surveillance using animals should be considered as a potential first-line surveillance approach for numerous zoonotic pathogens, through which baseline data on pathogen presence can be generated relatively quickly and cheaply on the national and international scales. The data generated could then be used to trigger additional surveillance and targeted resource investment.

6.4 Participatory epidemiology

Participatory epidemiology (PE) is a practical approach to epidemiology designed to give stakeholders a greater role in shaping public health and surveillance programmes. The approach attempts to recognise and utilise the very detailed existing knowledge that people have about the animals that they keep and about the infectious and zoonotic diseases that impact their health and livelihoods (Jost et al., 2007; Vetwork UK, 2011). Key PE techniques include semi-structured interviews, focus-group discussions, ranking/scoring exercises and a variety of visualisation techniques (Jost et al., 2007; Vetwork UK, 2011). Such approaches have been used around the world to gain understanding of disease transmission in a range of ecological and social contexts, and applied for the surveillance of a variety of diseases including a number of zoonoses (Jost et al., 2007; Bett et al., 2009; Freifeld et al., 2010; Jost et al., 2010).

Participatory approaches are about involving and engaging individuals so that they play an active role in the process of surveillance. This can lead to the creation of collaborative communities in which participants work to improve their health and that of others (Freifeld et al., 2010) and these approaches therefore provide a mechanism through which the communities that are at risk engage with the surveillance process, overcoming one of the key challenges of typically top-down surveillance approaches which frequently result in the neglect of data collection at the local/ground level. Because of the focus upon existing local knowledge, participatory approaches can lead to the development of disease control programmes that are both acceptable and effective in the context in which they are applied (Jost et al., 2007). In addition, because of the key assumption of PE that the investigator cannot fully anticipate the needs, priorities and problems of the community that they study, PE techniques are inherently flexible and "allow for the 'discovery' of new information" (Jost et al., 2007).

PE proved to be a particularly useful and sensitive tool for the identification of the remote and often isolated pastoralist communities in which the rinderpest virus persisted (Jost et al., 2007; Mariner and Roeder, 2010; Vetwork UK, 2011), where it was possible to utilise the clinical knowledge of pastoralists to identify foci of disease persistence and thus target eradication efforts effectively and cost-efficiently (Jost et al., 2007). The techniques developed through experience with rinderpest have since been applied to the surveillance of several important diseases including foot and mouth disease (FMD), peste de petits ruminants (PPR) and rift valley fever (RVF) (Jost et al., 2007, 2010) as well as to the surveillance and response to HPAI (Jost et al., 2007; Azhar et al., 2010). In Indonesia, an integrated participatory disease surveillance and response (PDSR) approach has been developed to better integrate disease detection and control activities for HPAI. In this setting, involving the community in the reporting of suspect HPAI cases has proved to be a highly efficient way of identifying new cases and successfully controlling outbreaks at the village level in more rural areas particularly (Azhar et al., 2010).

The potential weaknesses and criticisms of participatory approaches often relate to the nature and applicability of the data generated. PE techniques are often non- or semi-quantitative, the data generated can be difficult to code and store without losing much of the detail and as a consequence it can be difficult to standardise data. However, it can be argued that the particular value of the data generated through PE is the very detail that can be lost when trying to compare findings across settings and that this specificity to the particular context should be considered as a strength (Mariner and Roeder, 2010). Investigations of the 2006/7 RVF outbreak in East Africa revealed that knowledge of RVF in different Tanzanian and Kenyan communities was very variable (Jost et al., 2010) and illustrated the need for the collection, interpretation and response to data generated through PE within the local context. As with other approaches discussed in this section, it is argued that rather than being a catch-all answer to all questions, PE techniques should be used alongside others to enable comprehensive surveillance and response. For example, in the case of RVF surveillance and response, PE can be used alongside other techniques such as risk prediction based on climatic modelling. Prior to the 2006/7 outbreak, early warnings based on climatic models with high accuracy (including data on vegetation changes) were given but they provided warning of the outbreak too late to allow a preventive response (Jost et al., 2010). If less specific models that could provide an indication of high risk were combined with targeted enhanced surveillance employing PE techniques, the early warning could be provided by combining data sources and utilising the knowledge of the local populations affected (Jost et al., 2010). The overall flexibility of PE and the capacity of small but well-trained teams to generate substantial amounts of data with relatively low costs (Jost et al., 2007), suggests this tool could be explored more widely for specific zoonoses surveillance problems.

6.5 Surveillance using novel information technologies & data sources

Recent rapid developments in technological capacities for data collection and communication have had implications for the way in which health surveillance is conducted, and in many cases the use of electronic data collection and reporting systems has already improved detection of pathogens compared with older, manual methods (Bravata et al., 2004; Soto et al., 2008). Because of this, there is a hope that the use of novel technologies such as internet-based data extraction algorithms and mobile phones will enable global disease surveillance and facilitate great improvements in surveillance capacities within the developing world particularly. In many cases, the communications technologies discussed in this section are not in themselves surveillance systems and it is important to recognise that as with any other data collection tool, their considerable potential can only be realised if incorporated into well designed systems. However, the global adoption of new communication technologies, first the internet and more recently mobile phone connectivity, have undoubtedly provided opportunities and enabled a new class of participatory systems for global disease surveillance and monitoring (Freifeld et al., 2010).

6.5.1 Internet-based surveillance systems

In recent years, there has been a proliferation of new online data resources such as blogs, news outlets and discussion sites and of new data collection methodologies such as data-mining (a process of extracting patterns from large quantities of data) and crowdsourcing (a technique that involves engaging large numbers of people to perform a task) that can be used to access and utilise these data. The potential value of these non-traditional data sources and analytical tools for disease surveillance has in turn prompted a new generation of online disease surveillance systems such as ProMED, GPHIN, MedISys, HealthMap (Hitchcock et al., 2007; IOM, 2007; Brownstein et al., 2008). Many of these systems (See Appendix B) are designed to achieve early detection of emerging disease threats and for this purpose specifically, non-traditional data sources and proxy measures such as school and work absenteeism, calls to telephone care nurses, search engine query data and over the counter pharmacy sales have all been proposed as potential indicators of adverse health events that should be included in surveillance systems to provide an event signal earlier than more traditional surveillance data sources such as hospital admissions and mortuary reports (Bravata et al., 2004; Dailey et al., 2007; Ginsberg et al., 2009).

The use of automated electronic systems means that data on disease outbreaks can be processed and made available for access in near real-time at very low cost (Soto et al., 2008; Brownstein et al., 2009) and as a consequence, web-based systems are credited with being the first to detect a number of significant recent infectious disease events (e.g. reports of unusual respiratory disease in China were captured by ProMED-Mail and GPHIN prior to any official reports made during the SARS outbreak and in the period 1998-2001 the WHO outbreak and alert verification system confirmed 578 outbreaks of which 56% were initially detected by GPHIN (Hitchcock et al., 2007). However, this timeliness is achieved at some cost and key ongoing concerns regarding crowdsourcing and data-mining approaches include the question of how to corroborate or verify submitted information, and the potential risks of considerable negative economic and social impacts associated with false reports, generated either accidentally or when a system is 'hijacked' and used to spread malicious and unfounded rumours (Brownstein et al., 2009). Options for cross-validation and moderation of submissions are being explored (Brownstein et al., 2009; Freifeld et al., 2010), as it is argued that even when using data from sources that are perhaps biased or flawed in some way, the aggregation of several sources of data can be used to decrease the potential for false alarms, whilst maintaining the sensitivity and timeliness that is key for early warning (IOM, 2007).

ProMED is the exception amongst the global internet-based surveillance systems (See Appendix C) in that it uses in-country infectious disease experts to review and validate all reports prior to publication, leading to enhanced credibility of the published reports. In this way, ProMED retains the coverage, flexibility and timeliness of reporting that is key to these internet-based systems but also has enhanced credibility because of the manual validation of reports and is considered by many to be the model of an affordable system that may be suitable for resource-poor countries (Hitchcock et al., 2007).

Internet-based surveillance systems that continuously scour the web for health/ disease-related terms or reports have demonstrated utility for the early detection of health anomalies and potential disease outbreaks and their capabilities and value are likely to increase as these tools are refined over time (Ginsberg et al., 2009). However, such systems are inherently limited in developing countries, and particularly in rural areas where infrastructure is very poor, surveillance is weakest and livelihoods are most closely associated with animals. It is therefore important that investment in 'internet-based' systems does not compromise investment at the ground level, which cannot be replaced by a technological fix.

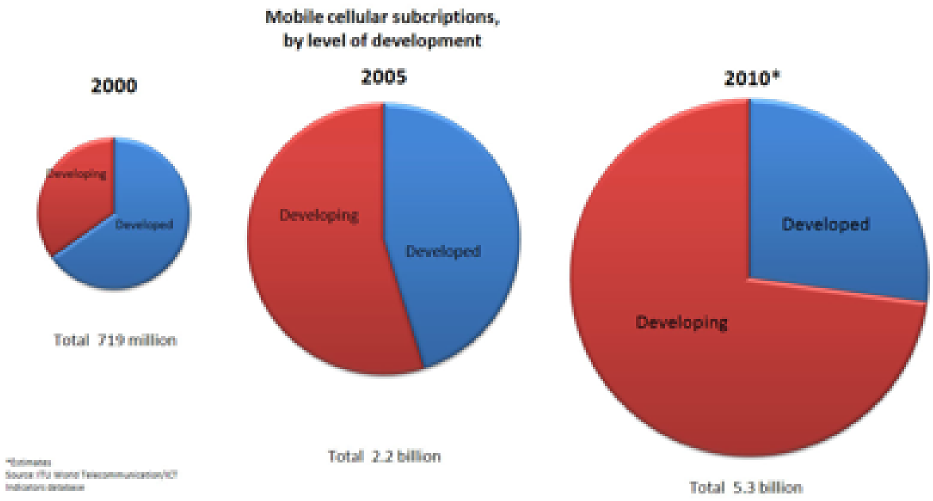

Figure 6.1: Illustration of the growth of mobile phone coverage in the developing world over the past 10 years. (ITU, 2011)

6.5.2 Mobile phone technologies

The use of mobile technology for disease surveillance and reporting offers the opportunity to develop improved integrated systems that are both time efficient and cost effective, as well as providing comprehensive geographic coverage. By 2009, 90% of the world's population was covered by a mobile signal and whilst both internet and mobile phone connectivity are growing, the rate of growth is much greater in the mobile phone sector and the most rapid growth in terms of subscriptions to mobile technologies is occurring in the developing world (ITU, 2011). By the end of 2010, mobile phone cellular user rates for the developing world will reach 68%, as compared to internet user rates of 21% (Figure 6.1; ITU (2011)). Effectively, telecommunications companies have already provided a global communications infrastructure that is inherently sustainable and can be utilised for disease surveillance purposes (IOM, 2007).

In terms of enabling comprehensive surveillance coverage of a population, the key strengths of mobile phones over desk-top or laptop based internet access are that mobiles are more portable, they consume considerably less power, can be charged for several days, can function in remote areas, are an already familiar and commonly used technology and can even be topped-up with credit remotely (Freifeld et al., 2010). The successful deployment of mobile phones equipped with software for reporting cases of infectious disease to a national database as an interim surveillance solution following the Sichuan earthquake highlights the potential of mobile technologies in areas with limited infrastructure (Yang et al., 2009).

Mobile phones and other electronic data collection/entry tools represent a considerable improvement over traditional paper and pen recording methods in that they reduce the number of error-prone translation steps between the initial collection of data and its use, enhancing both speed and accuracy (Soto et al., 2008; Yu et al., 2009; Mtema et al., 2010). These attributes make mobile phone based technologies particularly well suited to address deficiencies in disease surveillance capacities in the developing world, which have been chronically hindered by poor infrastructure and which currently represent the weak-spot in global surveillance capacities (GAO, 2001).

One of the first uses of mobile-phone technologies for disease surveillance in the developing world was through the Alerta electronic surveillance system, which has operated in Peru since 2003 (IOM, 2007). The Alerta system is focused on the Peruvian military and involves collection of extensive clinical data from a country-wide network of health-care facilities. Data on 45 diagnoses/syndromes are transferred from peripheral clinics to a central hub using a range of reporting technologies including mobile phones but also radio relay and internet. Captured data are displayed in real-time, automated data analysis conducted and feedback is given to stakeholders using a range of formats including e-mail and SMS (IOM, 2007; Soto et al., 2008).

One of the greatest strengths of surveillance systems that utilise mobile phones is this capacity for two-way transfer of information. Feedback to incentivise and enhance responses can range from automated responses that acknowledges receipt of a report, to reminders of follow-up clinic appointments and the provision of up-to-date data on drug stocks or the nearest source of vaccine (IOM, 2007; Soto et al., 2008; Mtema et al., 2010). A promising low-tech and easy to implement finding recently reported for HIV surveillance is that the use of SMS by healthcare workers improved patient adherence to antiretroviral treatment (Lester et al., 2010). It was suggested that SMSs improved the relationship between the patient and the healthcare worker in an area where healthcare access is typically very poor. Good relationships between patients, animal owners, healthcare and animal health workers (both within and between sectors) are necessary to improve the collection and quality of surveillance data. The potential value of two-way communication can operate on multiple levels, by for example providing a direct means of empowering staff to action a response (e.g. alerting the responsible person within the relevant sector), providing an outlet for communication with peers or colleagues and facilitating supervision. These attributes that are aided by mobile technologies have all been shown to improve health worker performance in low-income countries (Rowe et al., 2005) and are likely to be equally applicable to animal health workers.

There is now a large and rapidly growing number of mobile systems being piloted for public health. Several of the more developed mobile-based participatory systems for public health are described in Freifeld et al. (2010) and an inventory of mobile phone data collection applications (the majority of which are implemented in Africa) is maintained online
at: http://www.unglobalpulse.org/resources/mobile-phone-data-collection-inventory. Although a number of studies speculate on the potential of these technologies, there are few published evaluations of their impacts (Vital Wave Consulting, 2009). At the national level, mHealth initiatives are beginning to be implemented
(e.g. http://www.rollbackmalaria.org/psm/smsWhatIsIt.html), but very little research has been conducted on the factors that determine the sustainability and scalability of mobile technologies (Earth Institute, 2010).

In terms of animal disease surveillance though, the potential of mobile phone based systems has yet to be fully explored or exploited (Robertson et al., 2010). The Infectious Disease Surveillance and Analysis System (IDSAS) project in Sri Lanka represents one of the first examples of the application of this kind of approach to animal disease surveillance. The IDSAS project was designed to obtain timely animal health data from field veterinarians and involved mobile phone based submission of clinical data obtained by veterinarians during their normal daily work activities. A major output from this project, was the demonstration that mobile phone based surveillance of animal populations is both feasible and acceptable in lower-resource settings (Robertson et al., 2010). Several schemes are now also under-development in sub-Saharan Africa, such as the animal disease surveillance and response system (ADSARS) that is being rolled-out in Kenya (Knobel *pers comm.*) and the rabies surveillance system operating across sectors in Southern Tanzania (Mtema/Hampson *pers comm.*).

While there is a lack of cost-effectiveness studies for surveillance systems in general (See Section 4), quantifying the costs for the deployment of new technologies would be particularly valuable for determining whether such technologies are affordable in developing countries. The major expenses associated with establishing and running mobile-based surveillance systems are associated with the hardware required (Robertson et al., 2010) and a potential drawback with many of the mobile phone surveillance applications that are currently in development is that they rely on expensive smartphones which are not widely available in resource-poor settings. It is anticipated that as with previous generations of mobile phone technology, the costs of these smartphones will fall rapidly (Freifeld et al., 2010) but there is also an argument for designing systems that make better use of the kinds of phone technology that are already most widely distributed. Cheap java-enabled mobile phones ($\approx$ \$100/handset) are widely available in sub-Saharan Africa and the GSM network provides near universal coverage. Crude calculations suggest that mobile-based systems reliant on current (and rapidly improving) infrastructure could be extremely efficient to maintain. Sending a detailed report from a java-enabled mobile phone over the GSM network costs less than USD\$0.001 in Tanzania, while maintenance costs for a system piloted in Sri Lanka were estimated to be less than USD\$5/month per user (Robertson et al., 2010). These costs are potentially lower than paper-based reporting and would also allow more efficient monitoring of users. In the long-term, the capital costs of hardware are also likely to be compensated by reductions in the requirement for data entry time (Yu et al., 2009). However, the investment required for training users and the acceptability of mobile phones when deployed on a large-scale has yet to be seen, but preliminary studies indicate that time is needed to garner support for the implementation of alternative surveillance methods (Robertson et al., 2010).

Although systems such as Alerta are based on the use of proprietary software, open source software packages such as EpiSurveyor, RapidSMS, Java Rosa, FrontlineSMS and Nokia Data Gathering are all now widely used and technical support for in-country partners is provided online. The Open Mobile Consortium (OMC, http://www.open-mobile.org/) is a grouping of technical experts who collaborate to provide open-source technical solutions so that software can be cheaply and easily adapted for specific local needs, with the overall aim of enabling social change. A further obstacle though is that most computer scientists and software engineers in the developing world are rapidly employed by the more lucrative private sector. ICT specialists who can help establish and maintain such systems are particularly important in developing countries, given the inherent risks of switching from paper-based recording methods to electronic systems, which are magnified by frequent power outages. Incentives are therefore needed to attract qualified individuals who are capable of communicating effectively, navigating the public health/ veterinary sectors and are willing to work for the public sector.

One of the key lessons learned from the Alerta experience in Peru is the importance and value of building a surveillance system that makes the best possible use of existing capacities and networks. By building upon existing communications networks and hardware, and by making imaginative use of these tools, it is possible to rapidly create large-scale integrated networks for basic reporting without considerable investment in 'new' hardware and infrastructure (IOM, 2007; Soto et al., 2008). However, particularly, when designed to use existing infrastructure and personnel, there is the potential for the proliferation of mobile-phone based systems to overwhelm rather than assist existing surveillance networks. As the rapid growth in mobile phone applications for surveillance continues, care should be taken to ensure that integrated and efficient systems are established to meet the needs of stakeholders rather than generating a variety of parallel reporting systems each with their own focus and possibly different hardware and software requirements.

Mobile phone networks are unique amongst communication systems in their global coverage and accessibility. By enabling access to existing networks of people, mobile phones will perhaps provide the tool to address the key question of how to overcome the limitations of paper-based systems and get data from the ground into the system, particularly for those regions of the developing world that have been so badly served by existing surveillance systems. If used in combination with other novel approaches such as syndromic and sentinel surveillance, the use of mobile phone technologies offers the potential to generate comprehensive data on both animal and human health patterns in a timely and cost-effective way (Soto et al., 2008; Robertson et al., 2010), and ultimately to address the considerable gaps in global surveillance coverage that currently exist, for the developing world particularly.

6.5.3 Digital pens

Digital pens are electronic data capture devices that record hand-written text in digital format. Rather than acting as a replacement of more traditional paper-based surveillance data recording systems, the digital pen allows the simultaneous record of a both a paper-based and digital copy of recorded data. Digital pen data collection tools have been selected for trial by several southern African Veterinary Services because of the following advocated advantages:

- the approach is user-friendly in that it uses the pen and paper data collection processes;
- the training required for its use by animal health technicians is simple and short;
- the digital pen is more durable and less expensive than most PDAs or laptops
- use ensures the availability of a backup paper copy when technology fails.

Whilst enabling the transition to digital data collection and management, the digital pen is also something of a compromise technology in that its use can be integrated within more traditional paper based recording systems and may perhaps prove particularly useful in settings in which deficiencies in communications and technological infrastructures necessitate the maintenance of hard-copies of all data records.

6.6 Discussion

Common to all of these novel approaches is the ambition to achieve good surveillance coverage of a population by making better use of existing sources of data, whilst minimising costs and maintaining flexibility. Many of the approaches described above represent departures from traditional surveillance structures within which careful mechanisms for the control, verification and response to data have been developed and validated and there are concerns about this lack of coordination and regulation (Freifeld et al., 2010). It is important to recognise these limitations but also to acknowledge that these newer approaches are not proposed as alternatives to more traditional approaches, but should most usefully be considered as complementary tools that can be used to supplement rather than replace data generated from more traditional surveillance approaches (Brownstein et al., 2009; Freifeld et al., 2010). The value of many of these approaches is likely to be greatest in the developing world, where more traditional approaches have been found lacking particularly in terms of the coverage that they achieve.

It is also essential to recognise that the new communications technologies common to many of these novel approaches serve only as channels through which information is communicated and the fundamental role of the people who use that system cannot be overlooked (Brownstein et al., 2009). These innovations are also likely to be susceptible to the chronic problems of underinvestment that plague surveillance systems at the grass roots level unless there is a fundamental shift in priorities. As, with any choice about which surveillance system or tool to apply for a particular purpose it is always the case that there are a range of options and that no single technological tool or systems approach will be appropriate in all settings (IOM, 2007). Implementing electronic systems (and using new tools more generally) is more complex than simply applying a new technology (Soto et al., 2008) and it takes time and effort to generate support for novel surveillance methods amongst stakeholders (Robertson et al., 2010). After initial training in the use of new systems and technology, constant monitoring is also required to ensure that the system functions well (Soto et al., 2008). A surveillance system can be perfectly designed in terms of its technological components but if the users of the system have not understood its objectives and tools then the system will not work (Meynard et al., 2008). In all cases, care is needed in selecting the right combination of devices and systems for the purposes of any given surveillance and reporting activity and this selection is likely to be best aided by field trials with the active involvement of key stakeholders.

6.7 Conclusions

There is a growing literature on the use of innovative methods of monitoring zoonotic disease incidence and in the current context of discussions about the design of global surveillance system for zoonoses, the potential offered by less traditional surveillance approaches should be evaluated. This review of the literature on innovative surveillance approaches has identified a number of gaps in current knowledge and capacity in this area:

- Innovative surveillance approaches have mostly been applied to human health surveillance rather than animal surveillance or linked surveillance of both populations;
- There are relatively few examples of application of these approaches in developing country settings;
- There is a lack of systems for electronic capture of patient clinical data for storage or analysis, in the animal sector especially. This capacity gap applies to both the human and animal sectors in many developing country settings, limiting the options for application of analytical techniques that can detect for example changes in health-seeking behaviour or unusual disease syndromes;
- There is a lack of standardised disease-coding systems for animal diseases and syndromes (analogous to the ICD systems in the human sector). This deficiency greatly complicates the analysis and comparison of disease incidence data across communities. Even in the human sector, those systems that do exist are not always systematically applied and as a consequence there are no accessible baseline data against which 'new' data can be compared.
- There is a lack of inexpensive and simple diagnostic tests that can be readily adapted and applied to samples collected from a range of animal species
- There has been little work on the quantitative methodologies that can be used to link and analysis data from human and animal populations

To address many of these deficiencies, we recommended a single solution, namely investing in trialling these approaches further. In terms of the likely priority settings for surveillance investment - namely rural areas in developing countries in which widespread livestock-keeping and current infrastructural deficiencies combine to ensure relatively high risks and impacts of zoonotic disease - we would argue that investment should be focused towards:

- development and field trialling of mobile-phone based automated animal and human health data collection and manipulation systems that ensure that information is made available for analysis and feedback in a timely manner;
- these systems may be based on the collection of many types of data and should prioritise two-way communication to enhance sustainability
- these systems can be explicitly designed to benefit data collectors through for example the provision of diagnostic support and information feedback (See Section 5);
- the use of participatory epidemiology approaches to examine local understanding of zoonotic disease risk, determine local priorities for surveillance and control and identify locally appropriate potential interventions;
- the use of sentinel and syndromic surveillance approaches to gather broad-scale baseline data on animal disease incidence.

In all cases these approaches should be designed and implemented to enable ongoing evaluation of the system and include assessment of reporting practices by the different stakeholders involved. There is also a need to design and evaluate systems for turning observations of disease in animals into useful advice regarding human and animal risk and possible behaviour modifications.

Chapter 7

Surveillance budgets

7.1 Summary

Data on the budgets for livestock and human disease surveillance and monitoring activities at both the international and global levels can be used to provide estimates of the additional investments required to achieve an effective global surveillance system for zoonoses. However, data on the costs of surveillance at both the national and international levels and on the availability of funds for surveillance and monitoring activities are not readily accessible. Here, we present data from the small number of studies that have attempted to quantify the costs of surveillance for influenza and zoonoses on the global scale, national veterinary health systems and integrated human health systems in developing country settings. The data presented highlight the current deficiencies in the quantity and quality of data on the costs of surveillance activities as well as the lack of systems and methodologies that exist to enable collection of these data.

We identify four research and policy areas to target for future investment:

- The methodological means of collecting the required data on surveillance costs at the national and sub-national levels.
- The lack of evidence required to allocate international resources for surveillance improvements according to need

- The current lack of incentives to collect these data at the national level and share them with the international community
- The lack of an assessment mechanism for demonstrating the value of investment and the impacts that are achieved

To address these deficiencies and develop more accurate estimates of the costs of zoonosis surveillance, both the proximate and ultimate explanations for these current data gaps must be addressed. Specifically, methodological studies targeted at designing and field-testing new data collection tools will be required and we advocate the adaptation of existing international tools such as the WHO IHR and OIE PVS to include the collection of data on both surveillance costs and performance that can be compared across national settings. To incentivise the use of such tools we argue that the provision of donor funds to enhance national surveillance capacities could be made contingent upon participation in such a data collection and assessment scheme. This will encourage the collection of these standardised data on both costs and performance, simultaneously enhancing the volume and quality of data available to quantify surveillance costs and also providing a mechanism for the assessment of the value of investments made in relation to performance enhancements achieved.

7.2 International surveillance

Traditionally, individual countries have taken responsibility for funding their own surveillance systems. However, the global nature of the threat posed by H5N1 influenza A and recognition that many low-income countries lacked the resources to provide sustainable funding for surveillance and response activities prompted the development in 2005 of new global systems of financing and collaboration adopted to meet this challenge. At a meeting of international partners in 2006, a financing framework for fighting animal and human influenza on the global scale was developed and as of October 2008, donors had committed US$2.0 billion to this framework. The funds have been divided to support country programmes (US$853 million), international organisations (US$510), regional programmes (US$301) and other recipients, including research (US$386) (FAO et al.,

Table 7.1: Financing gaps for country-level control programmes for avian and human influenza (Based on funds committed as of April 008, US$ million) (FAO et al., 2008; The World Bank, 2010)

Region	Needs (2006-2008)	Available financing	Remaining gap
Sub-Saharan Africa	589	149	440
East Asia and Pacific	935	656	279
Europe and Central Asia	247	228	19
Latin American and Caribbean	17	17	0
Middle East and North Africa	233	150	83
South Asia	149	134	15
All regions	2,170	1,334	836

2008; The World Bank, 2010). For each country included, individual estimates of the funding required for national programmes to achieve control of avian and human influenza specifically were made, as well as quantification of the actual funding available and the remaining shortfall. These figures are summarised in Table 6 (FAO et al., 2008) (Details of the methodology for these estimates are given in FAO et al. (2008)). More than half of the overall financing gap identified in the international effort to control influenza was associated with insufficient resources to tackle influenza in Sub-Saharan Africa, and there were also considerable deficiencies in the East Asia and Pacific and Middle East and North Africa regions (FAO et al., 2008; The World Bank, 2010).

Based on the experiences of financing the international response to recent influenza A threats, estimates have been made of the costs of funding a “One World One Health” (OWOH) framework, that would serve as a permanent global surveillance system and function to ‘diminish the risk and minimise the global impacts of epidemics and pandemics due to emerging infectious diseases’ (FAO et al., 2008; The World Bank, 2010). The estimated budget required to fund such a framework is summarised in Table 7.2. In brief, the cost estimates were generated at the country level and are based on the human and livestock populations of each country, the land area for wildlife and the costs of developing and maintaining infrastructure (based on the economic status of the country). Further details of the methods and costs sources used to generate these estimates are given by The World Bank (2010). These figures are of course based on a number of assumptions and the estimation of the levels of risk that are acceptable to the global community are particularly hard to pre-define. As a consequence, the

Table 7.2: Estimated costs of funding a 'One World, One Health' (OWOH) framework to 2020 (US$ million, IDA = International Development Association, IBDR = International Bank for Reconstruction and Development) (FAO et al., 2008; The World Bank, 2010)

Cost	49 Low-income countries	All 139 eligible countries (IDA and IBRD eligible)
Public health services	1,264	3,083
Veterinary services	3,286	5,476
Wildlife monitoring	1,495	2,495
Communication	583	1,167
International organisations	3,180	3,475
Research	420	420
Total	10,228	16,116
Average per year	852	1,343
Average per country for the period	208	116 (*average for middle income countries only*)

authors of these estimates themselves recognise that generating such estimates "is an art, not a science" (The World Bank, 2010).

7.3 National animal health surveillance

At the national level, a recent study was conducted to estimate the 'peace time' costs of Veterinary Services and the overall cost of national prevention systems for animal diseases and zoonoses in developing and transition countries (Civic Consulting, 2009). The authors of this report developed a methodology for direct measurement of expenditure on National Prevention Systems (NPS, defined as, "Sum of all services and activities of the public Veterinary Services and other relevant public providers at national and subnational level allowing early detection and rapid response to emerging and re-emerging animal diseases, including the services accredited to private veterinarians undertaking public service missions financed from the public budget") and applied this approach to

Table 7.3: Summary costs of NPS in 7 countries for 2007. All figures are in international dollars. Costs covered by donor programmes not included. (Data from Civic Consulting, 2009)

Country	Total NPS Costs (000)	NPS Costs per VLU
Costa Rica	11,172	8.18
Kyrgyzstan	10,043	5.69
Mongolia	21,086	3.30
Morocco	46,811	7.25
Turkey	166,962	9.40
Uganda	16,888	1.92
Vietnam	67,356	3.85

assess expenditure in seven case study countries (Costa Rica, Kyrgyzstan, Mongolia, Morocco, Turkey, Uganda and Vietnam) (Civic Consulting, 2009). The authors faced a number of methodological challenges during this assessment including the principal problem of the poor availability of data. Attempts to obtain data on NPS costs remotely were unsuccessful and they were only able to generate the cost data required by physically visiting the study countries and directly compiling the data on site (Civic Consulting (2009) & Alleweldt *pers. comm.*). National expenditure on NPS varied considerably between countries (from \$10,043,000 in Kyrgyzstan to \$166,962,000 in Turkey. See Table 7.3). Expenditure did vary with the size of the national livestock population (quantified as Veterinary Livestock Units (VLU)) and there was a 'strong' association between GDP and total public expenditures for National Prevention Systems. Concerningly though, the data also indicate that expenditure on national prevention systems was more of a reflection of a country's capacity to pay, than of its veterinary requirements (Civic Consulting, 2009).

Staff costs represented up to three quarters of all NPS costs in the case study countries, and better data on the number of staff employed at all levels of the public Veterinary Services would therefore greatly enhance capacity to quantify expenditures for additional countries (Civic Consulting, 2009). Such data are currently published through the OIE WAHID website but the accuracy and detail of these data are limited and the authors also found that the central public Veterinary Services in a number of the countries visited were not aware of the number of veterinary personnel at the sub-national level (Civic Consulting, 2009). With such basic deficiencies, it is currently very difficult to quantify investment in animal population surveillance with any real degree of accuracy. The authors of this OIE funded study noted that there were very few existing data on the costs of veterinary surveillance systems prior to their report (Civic Consulting, 2009).

7.4 National human health surveillance

There is a larger literature on the economics of health surveillance in the human sector but the majority of studies conducted to date have focused on individual diseases and few have looked at the costs of surveillance overall (Somda et al., 2009). The WHO African region has adopted a regional strategy, the Integrated Disease Surveillance and Response (IDSR), through which member countries undertake to improve infrastructure and capacities required for the surveillance of a number of priority communicable diseases. A recent study analysed the incremental costs of establishing and operating surveillance under the IDSR scheme and compared these to overall surveillance costs (Somda et al., 2009). This study was similar in design to the assessment of the cost of veterinary surveillance systems described above and involved collection of data on the costs of all human health-related surveillance and also included costs that were specifically attributable to the IDSR. These data were collected specifically for this study using newly designed data collection tools, again revealing the absence of existing data on which to base this kind of assessment (Somda et al., 2009) The costs of health surveillance activities for three African countries are summarised in Table 7.4 and Table 7.5.

As for veterinary surveillance systems, personnel costs represented a considerable proportion of all annual human health-related surveillance costs at the regional (10-47%) and district levels (16-44%) in the study countries (Somda et al., 2009). Overall, there is considerable variation in costs of human disease surveillance across these study countries and full understanding of this variation will require further study (Somda et al., 2009). It is therefore, very difficult to extrapolate from these data at present to generate estimates of surveillance costs in other countries and settings.

Table 7.4: Mean annual costs (in 2002 US $) of all human disease surveillance systems in three African countries (over the period 2002-2005) (Somda et al., 2009)

Country	Health structure level (n units)	Mean annual costs of all disease surveillance systems
Burkina Faso	Region (4)	137,566
	District (14)	51,296
	Primary health care centre (20)	5,196
Mali	Region (3)	111,584
	District (3)	51,354
	Primary health care centre (3)	5,851
Eritrea	Province (1)	205,333
	District (1)	28,220

Table 7.5: Mean annual per capita disease surveillance and total health care costs (in 2002 US $) for three African countries (over the period 2000-2005) (Somda et al., 2009)

Country	All health-related surveillance	Total IDSR strategy	Total National expenditure on health	Govt. only National expenditure on health
Burkina Faso	0.136	0.036	15.86	6.86
Eritrea	0.66	0.157	8.14	4.86
Mali	0.05	0.020	13.60	7.00

At the global level, the WHO national health accounts (NHA) scheme is designed to allow monitoring of trends in health funding, allocation and spending at the national and regional level, by providing an accounting framework that can be consistently applied across countries. Guidelines for the production of NHA at the country level include consideration of activities such as ‘reporting/notification of certain communicable diseases and epidemiological enquiry of communicable disease’, which would fall within most definitions of monitoring and surveillance. Unfortunately however, a range of activities consistent with surveillance and monitoring are included under two distinct health care function definitions (HC.6 and HC.7) and both classifications also include activities that would not be included in many definitions of surveillance (WHO, 2003). As a consequence, there is no mechanism at this time for extracting costs allocated to surveillance activities specifically from NHA. This problem recurs with other budget systems, as mechanisms for the allocation or partitioning of costs to a surveillance budget stream are rare and there are consequently few methods and resources that allow the quantification of a 'surveillance budget'.

7.5 Discussion

Overall, it is currently extremely difficult to identify and compare data on budgets and expenditure for surveillance for both the animal and human health sectors. Considerable gaps exist in the availability of accurate data on surveillance costs and in those cases where data or at least approximate estimates are available, they reveal additional funding gaps in the resources required to carry out surveillance control in the developing world (FAO et al., 2008; The World Bank, 2010). A key explanation for the current absence of good quality surveillance budget data is that it is very difficult to define expenditure on surveillance. Many activities that are considered part of a surveillance system are also considered as part of other systems and are therefore also covered under other budgets and the allocation of these partial costs to surveillance is not straightforward. Data on the costs of surveillance are also not always made publicly available. This may often be due at least in part to the difficulties in defining surveillance costs but there are also likely to be a range of explanations for reluctance to share those data that do exist which will themselves vary across settings (See Chapter 5). In resource limited settings, the upfront investment required to assess either the costs or performance of surveillance systems can be difficult to justify when faced with immediate demands on resources and the probable lack of funds to meet the future costs identified. In those cases where at least approximate estimates of the funds required to achieve effective surveillance are available, they reveal particular gaps in terms of the availability of funds required to carry out disease surveillance and control in the developing world (FAO et al., 2008; The World Bank, 2010).

7.6 Conclusions

Several major gaps have been identified in current capacity that greatly limit the use of data on the costs and budgets available for surveillance to inform the allocation of future resources. These include:

- The methodological means of collecting the required data on surveillance costs at the national and sub-national levels;
- The lack of evidence required to allocate international resources for surveillance improvements according to need;
- The current lack of incentives to collect these data at the national level and share them with the international community;
- The lack of an assessment mechanism for demonstrating the value of investment and the impacts that are achieved.

In order to tackle the following gaps in capacity several linked approaches should be taken:

- Methodological research should be conducted to develop and 'field-test' techniques for allocating costs to zoonosis surveillance. This will involve the development of common standards and guidelines for partitioning the costs of activities that contribute to surveillance in both the animal and human sectors and for collecting these data, initially at the national level. Existing techniques and tools developed for the human health setting (e.g. WHO NHA and see Civic Consulting (2009)) can be adapted and applied to the animal health and zoonoses surveillance contexts. This process should involve representatives from both sectors to ensure the applicability of tools for both settings and also the explicit inclusion of zoonosis surveillance specific costs that involve investment of resources from both sectors;
- For the international community to invest in improving the global system as a whole it is important to develop standard measures of surveillance system performance so that investments can be most effectively targeted to current capacity

gaps. Adaptation and expansion of existing internationally applicable tools for performance assessment such as the IHR and OIE PVS is advocated;

- On the international scale, the provision of funds by the international community to first assess and then enhance national level surveillance capacities could be made conditional upon compliance with a system for quantifying the costs and identifying shortfalls in current funding whilst simultaneously assessing the current status of surveillance systems and identifying targets for future improvement. In this way, the collection of data on costs and performance at the national level would be encouraged by enhancing the probability of receiving international funds to tackle the deficits identified;

- One option that has been advocated to ensure effective use of funds provided for an international surveillance system is to link economic indicators of investment requirements with assessments of surveillance sector performance (Civic Consulting, 2009). If the provision of donor funds to recipient countries was conditional on compliance with a scheme based upon the existing IHR and OIE PVS systems to define and quantify both costs and performance, this would simultaneously improve the accuracy of the estimates of the investment required, provide performance benchmarks that resources could be targeted to achieve and also to improve the transparency of the system and enable better evaluation of the impacts of investments provided.

Chapter 8

Synthesis of findings

8.1 Summary

The principal objective of this study has been to provide advice on future priorities with respect to the identification of zoonoses hotspots. To do this, it is essential to make a clear distinction between disease emergence hotspots and existing hotspots of endemic zoonoses, disease epidemics and neglected tropical diseases (Perry et al., 2011). Much of the recent thinking about where to conduct surveillance of zoonoses has focused upon the identification of zoonosis emergence hotspots (Jones et al., 2008; PREDICT Consortium, 2010) at which novel pathogens may emerge in future. We argue that from a development perspective particularly, there should instead be a focus upon tackling and reducing the considerable negative impacts of zoonoses upon the global population. This can be achieved by focusing investment in surveillance upon areas of the world in which zoonoses are currently imposing considerable burdens and upon those pathogens for which cost-effective options for disease control already exist (Molyneux, 2008; Maudlin et al., 2009).

Effective surveillance is essential to identify and ultimately control these existing zoonoses hotspots. As discussed in this report, many of the data required to use traditional data-based surveillance methods to identify existing zoonosis hotspots and priority areas for investment are currently lacking and the historical negative influence that this lack of data has had upon investment in zoonotic diseases has been widely documented (Maudlin et al., 2009). There is a need therefore to simultaneously address these data gaps and also employ new surveillance methodologies that are not dependent upon these traditional but flawed data sources.

The provision of an effective human and veterinary public health response to tackle zoonoses is dependent upon the acquisition and processing of comprehensive, accurate and timely information on both public health threats and capacities to address them. Obtaining, interpreting and acting upon these data are the core functions of any surveillance system. Although the fundamental value of surveillance activities is rarely disputed, there are many cases and settings in which there has been insufficient investment in surveillance capacities and these have contributed to considerable gaps in capacity on the global scale. The challenge is to understand the factors that have contributed to these gaps and to identify ways of addressing them.

The wide range of stakeholders involved in the design and operation of zoonosis surveillance systems creates potential for conflicts of approach resulting from the different motivations and viewpoints. However, it is increasingly recognised that by focusing on the common capacities required by the surveillance systems that would benefit all stakeholders, the apparently disparate requirements of these groups can and should be reconciled and inclusive systems conceived (King et al., 2006; FAO et al., 2008; The World Bank, 2010). To achieve this, investment must be focused towards building surveillance systems that include surveillance of both animal and human populations and include both endemic and pandemic (or epidemic) pathogens (FAO et al., 2008; The World Bank, 2010). The core capacities required for the effective surveillance of all pathogens are common, and investment in any system designed to tackle zoonoses overall, rather than a single pathogen in isolation is likely to lead to grassroots level benefits on a locally relevant disease-by-disease basis, whilst simultaneously enhancing the capacity of national and ultimately global systems to detect and respond to all zoonotic threats (FAO et al., 2008).

It is important that the best possible use is made of existing surveillance capacities and that future investment is directed towards achieving better integration of existing systems and to identifying and filling gaps in coverage. Many of the greatest benefits achieved through previous investments in surveillance capacity have been through the development of core surveillance capacities, and the 'successful' systems are frequently those that have built upon existing capacity to adapt and tackle new surveillance challenges (e.g. the expansion of the Global Polio Eradication Initiative network to tackle multiple pathogens, and see (Hitchcock et al., 2007; FAO et al., 2008; The World Bank, 2010; Wilson et al., 2010)). Key advantages of this kind of approach include avoiding duplicating resource investment, not alienating members of established systems and developing locally appropriate systems. A model for this type of system integration is provided by integrated disease surveillance and response (IDSR) systems developed in the human health sector. The IDSR approach involves recognition that surveillance activities for different diseases often involve similar functions, structures, processes and personnel and promotes the integration of common activities to achieve cost-effective use of resources (Somda et al., 2009). Although there are additional challenges associated with bridging disciplinary boundaries, this model can be extended beyond human health to encompass the animal health sector. This is to some extent already happening, and the recent edition of the WHO/CDC IDSR guidelines for the Africa region emphasises the 'One World, One Health' perspective, and the potential for integration across these disciplines (WHO and CDC, 2010).

The recently proposed international framework through which global zoonosis surveillance can be enhanced (FAO et al., 2008) is a multi-pathogen system overall but in practical, on the ground terms it will involve focusing on individual pathogens at the national or regional level. The funding model where funds were distributed at the country level was key to the successes of global efforts to contain influenza A outbreaks (FAO et al., 2008; The World Bank, 2010) and the encouragement of in-country capacity building is also seen as key to the sustainability of such investments (Hitchcock et al., 2007). After allocation at the national level, the targeting of future investments in zoonosis surveillance should be based on the assessments of 'priority diseases' at the national and sub-national levels. The reasons for the historical neglect of endemic zoonoses across developing countries include the fact that these diseases affect predominantly poor and marginalised communities, and that current tools for priority setting such as burden of disease measures have penalised endemic zoonotic pathogens particularly (Maudlin et al., 2009). As a result, policy-makers have had little interest in committing resources for disease surveillance or control, which perpetuates the cycle of neglect. It is also clear that priority setting for resource investment has also been distorted by disproportionate media attention and fear and there is a need for the development of more rational tools for the assessment of zoonotic disease impacts and priority setting at the country level that better describe the considerable burdens imposed by endemic pathogens as well as the potential threats associated with emergence events.

Despite considerable improvements over recent years, there is still a need to facilitate greater geographical and disciplinary integration for zoonosis surveillance and two key changes in perception are required. First, a shift to a global mindset (amongst policy-makers and funders particularly) (Hitchcock et al., 2007) and second, a universal need to build understanding of one health approaches in order to overcome the prevailing perception of "Us vs. Them" and foster an understanding of "Shared Risk" (Rabinowitz et al., 2008). In the developing world especially, where investment in surveillance has been limited, there is a need to effectively create a 'culture of surveillance', which is essential to the effective functioning of any surveillance system (Soto et al., 2008). To achieve this, investment is required in the key resource and capacity of any surveillance system, the people that the system consists of (Robertson et al., 2010). The first step in this process will be to identify the networks of people from both the public and private sectors that are potential reporters but who are currently under-utilised for surveillance. This may include, for example, health care workers, veterinary professionals, farmers, butchers, abattoir workers and a range of other groups. Social network analyses of these groups could help to identify key data providers and maximise the efficiency and cost-effectiveness of their inclusion within reporting networks (Hoinville et al., 2009). Having identified these potential participants in surveillance, social science investigations should be conducted to try to understand current barriers to their inclusion within surveillance systems and to explore how those barriers could be overcome. At this point, the potential value of less conventional data sources and communications tools in enabling reporting by these different stakeholders should also be considered as the key potential benefit of using novel data collection approaches and technologies lies in the capacity to empower networks of stakeholders to contribute to surveillance (IOM, 2007). Within a surveillance system, stakeholders need to understand why surveillance is valuable, why their efforts are useful and that their time is not being wasted (Soto et al., 2008). In those cases where effective surveillance systems have been established in developing world settings, education has been identified as the key solution relating to the inclusion and action of people within the system (Soto et al., 2008; Robertson et al., 2010). Establishing a 'notification culture' is not something that will happen rapidly, it can take many years and will require political support and considerable investment (Soto et al., 2008).

This approach to designing better systems for zoonosis surveillance will also require the development of new tools for the assessment of existing capacities, identification of gaps in coverage and a new social science influenced approach to the understanding of when and why individuals at all levels in surveillance systems do or do not act to detect, report or respond to individual pathogens. Developing these approaches will take time and in practical terms, we propose that future research and investment should initially be focused upon a small number of developing world countries in which local scale in-depth case-studies could be conducted. The selection of these sites should be based upon existing knowledge and informed by subject and pathogen specific experts. Ideally, these sites should be 'current' zoonoses hotspots that are at sites of interface between humans, livestock and wildlife populations. They should also be focused in areas for which existing data indicates that investment in the control of an endemic zoonosis could have the greatest beneficial impacts upon both human and animal health. In each site, the first steps should involve the description of any existing surveillance systems (both animal and human) and the full range of stakeholders involved, followed by an assessment of where there are current gaps in coverage and identification of the existing barriers to effective surveillance and response (see Baker et al. (2010)). Although the combination of barriers and obstacles that apply in different settings, as well as the appropriate responses, will vary, the focus upon a small number of sites in the first instance will provide a context in which the tools required to make these assessments on a wider scale can be developed.

The longer-term sustainability of any surveillance system depends on the degree to which participation in that system achieves an appreciable useful response and upon the degree to which the provision of that response does lead to ongoing investment by stakeholders in maintaining and contributing to the surveillance system. It is therefore essential that these case studies are designed to generate two key outcomes. First, to develop and implement locally appropriate and effective control programmes for the important endemic zoonotic pathogens at each site and second, to develop monitoring systems that provide feedback on both the efficacy of the control measures implemented (in terms of epidemiological impact upon the target pathogen), and also on the degree to which the provision of a useful response does function to encourage reporting and engender an understanding amongst stakeholders about the value of ongoing surveillance. These data would enhance understanding of how to tackle existing problems with zoonotic diseases and also help to better understand how a culture of surveillance can be achieved, so that successful strategies could be adapted and applied across other settings with the ultimate aim of reducing the multiple burdens of zoonotic pathogens.

Appendix A

Terms of Reference

Terms of Reference:

Zoonoses (Project 3)
Surveillance and monitoring of zoonoses

Introduction
A study on the costs and benefits of surveillance and monitoring of selected zoonoses

Objective: The objective of this study is to provide advice on future priorities with respect to the identification of potential zoonoses hotspots. To do this the study will critique of the costs and benefits of surveillance and monitoring of key neglected (e.g. cysticercosis and brucellosis) and emerging (e.g. avian and swine flu) zoonoses and identify lessons of the usefulness of past investments in surveillance and monitoring systems.

The Scope:
The scale of investment in surveillance and monitoring systems is understandably very variable around the world. OECD countries have high levels of surveillance while many developing countries (especially those which don't export livestock or livestock products) have little incentive to invest. This disparity results in maps of the origins of the emergence of disease which are biased by data availability. It is not only the cost, however, which limits the usefulness of the data. There is also a disparity between countries in the accuracy of the data recorded, due to differences in the incentives/regulations with respect to accurate reporting of the incidence of zoonotic diseases. A further issue relates to the perceived disadvantages to some countries of sharing the information collected.

The consultants will be expected to address the objective by undertaking the following tasks:

i) undertake a Systematic Review of where (geographically on a global basis and in terms of impact and by public/private sector) surveillance of livestock disease and human disease is being carried out. Assess what has or has not been cost-effective and the underlying reasons;
ii) analyse the issues surrounding the recording, reporting and acting upon such surveillance data in developing countries from a socio-economic perspective (e.g to include consideration of governance arrangements, capacity for handling data and constraints to sharing data);
iii) review the literature (published and emerging) on innovative methods of monitoring zoonotic disease incidence including the use of proxy indicators (e.g. animal productivity);
iv) summarise the budgets for livestock and human disease surveillance and monitoring activities at both national and global levels;
v) analyse all the information gathered and provide a synthesis report which identifies the lessons of the usefulness of past investment and can be used to inform decisions on future priorities for investment with respect to the identification of potential hotspots.

Terms of Reference:

Expertise in team:
It is expected that a multi-disciplinary team will be required to undertake this piece of work including economists, social scientists, vets, and experts in governance and data management.

Reporting
The supplier will report to a Steering Group chaired by Professor Maggie Gill, Senior Research Fellow in DFID and which will involve DFID and partners from international organisations and UK research funding bodies.

Two separate but complementary studies are being externally commissioned at the same time on*:' Characterising livestock systems zoonoses hotspots' and'Wildlife/domestic livestock interactions'*. One of the roles of the Steering Group will be to facilitate interaction between the projects (where appropriate) and thus it will include sufficient disciplinary expertise to cover all aspects of the 3 projects.

An inception meeting will be held with the Steering Group within the first 2 weeks of the project and either a written or verbal report is expected to be given to the Steering Group half way through the project. A draft final report will be submitted at least 2 weeks before the workshop, a presentation made at the workshop and the report finalised within one month of the workshop.

Output: The main outputs will be a written report and a presentation at a workshop as a follow-up to the one held in December 2009.

Timeframe
The workshop (to be organised by DFID) is expected to be held early in 2011.

Background
A workshop entitled: 'Potential for policy interventions to minimise the risk from zoonoses as livestock systems respond to growing demand´ was organised by DFID in December 2009 **to examine the proposition that: 'the identification of potential hotspots for the emergence of zoonoses has the potential to lead to the identification of interventions which would mitigate that risk'.**

The workshop was attended by 37 participants including representatives from FAO, World Bank, OIE, GTZ, European Commission and UK Research Councils. The following Key issues were identified and conclusions reached.

Key Issues and Conclusions:

1. While the intensification of livestock systems is an important driver, it is also how these systems interact with wildlife that is crucial to new zoonotic disease entering the human environment. Understanding these interactions and how land use changes influence the nature of these interactions is important to further our knowledge of potential new outbreaks.

Terms of Reference:

2. There are significant gaps in our knowledge and scope for further research, but there should be greater consideration given to the questions that need answered and who the end users of research are before deciding on research commissioning.

3. Enhanced surveillance and monitoring would provide useful information but there needs to be greater evidence that this is cost effective as well as addressing issues surrounding capacity and how this knowledge is managed and shared.

4. While emerging zoonoses often have their base in neglected or endemic zoonoses and there is significant overlap between the two groups, policy makers see them as quite separate issues. The overlap in relation to disease emergence merits a higher profile.

5. There needs to be a greater appreciation of how policy is made and how the international and national political, economic and social environments influence decisions.

6. Communication of the risk and the impact of zoonoses needs to improve.

7. A broader group of experts should be included in the discussion, including more representatives from developing and rapidly urbanising countries, veterinary, medical and public health groups, knowledge management and the modelling community.

Many discussions on tackling zoonoses end with recommendations on the need to improve surveillance and monitoring systems, based on the cost of infectious disease (estimated at £3bn for avian 'flu). A comment was made in the workshop discussion that '*current best estimate to build an effective surveillance system is around $8 bn a year over 8 years*'. One of the aims of this project is to challenge that statement with evidence.

No next steps were agreed at the workshop, but there was no doubt amongst the participants that zoonoses is a major policy area where evidence is lacking. There remain significant gaps in our knowledge and there is a need for more evidence to properly frame the questions that need answered.

A copy of the workshop report can be accessed at:
http://www.livelihoodsrc.org/project-page.php?id=25

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Format for Proposal:

Should be on the form included as Annex A

Payment

Money should be invoiced after the inception meeting, delivery of the mid-way report and after acceptance of the final report.

Appendix B

Surveillance System Classification

Table B.1: Summary of surveillance systems identified through the review of the grey literature

System Identified	Ongoing Surveillance?	International?	Zoonoses?	Multiple Pathogens?	Human Only?	Animal Only?	Animal & Human?
AFENET	No	-	-	-	-	-	-
ALERTA	Yes	No	Yes	Yes	Yes	No	No
ARBO-ZOONET	No	-	-	-	-	-	-
ArboNET	Yes	No	Yes	Yes	No	No	Yes
Argus	No	-	-	-	-	-	-
AVMA National Zoonotic Disease Infectious Disease Surveillance System	No	-	-	-	-	-	-
BioCaster	Yes	Yes	Yes	Yes	No	No	Yes
BOSSS	Unclear	No	Yes	Yes	No	Yes	No
CDC GDD	Yes	Yes	Yes	Yes	No	No	Yes
CIMTRADZ	No	-	-	-	-	-	-
DEFRA RADAR	Yes	No	Yes	Yes	No	Yes	No
DEZIT Thailand Zoonotic Surveillance	No	-	-	-	-	-	-
Distribute	Yes	No	Yes ?	Yes	No	No	No
DoD GEIS	Yes	Yes	Yes	Yes	No	No	Yes
Early Warning Outbreak Recognition System (EWORS)	Yes	Yes	No	Yes	Yes	No	No
ECDPC Programme on food- and waterborne diseases and zoonoses (FWD)	Yes	Yes	Yes	Yes	Yes	No	No
EFSA Zoonoses Monitoring	Yes	Yes	Yes	Yes	No	No	Yes
EIP CDC	Yes	No	Yes	Yes	Yes	No	No

System Identified	Ongoing Surveillance?	International?	Zoonoses?	Multiple Pathogens?	Human Only?	Animal Only?	Animal & Human?
Emerging Infections Network (EIN)	Yes	Yes	No	Yes	Yes	No	No
EMPRES	Yes	Yes	Yes	Yes	No	Yes	No
EmZoo	No	-	-	-	-	-	-
EnterNet	No	-	-	-	-	-	-
EpiSpider	Yes	Yes	Yes	Yes	No	No	Yes
ESSENCE	Yes	No	No	Yes	Yes	No	No
FoodNet	Yes	No	Yes	Yes	Yes	No	No
GAINS	Yes	Yes	Yes	Yes	No	Yes	No
GeoSentinel	Yes	Yes	No	Yes	Yes	No	No
GF-TADs (Global Framework for the progressive control of Transboundary Animal Diseases)	Yes	Yes	Yes	Yes	No	Yes	No
GLEWS	Yes	Yes	Yes	Yes	No	No	Yes
Global Foodborne Infections Network (GFN) (was Global Salm-Surv)	Yes	Yes	Yes	Yes	No	No	Yes
Global Influenza Surveillance Network (WHO)	Yes	Yes	Yes	No	Yes	No	No
GOARN	Yes	Yes	Yes	Yes	No	No	Yes
Google Flu Trends	Yes	Yes	Yes	No	Yes	No	No
GPHIN	Yes	Yes	Yes	Yes	No	No	Yes
HealthMap	Yes	Yes	Yes	Yes	No	No	Yes

System Identified	Ongoing Surveillance?	International?	Zoonoses?	Multiple Pathogens?	Human Only?	Animal Only?	Animal & Human?
Highly Pathogenic Avian Influenza Early Detection Data System (HEDDS)	Yes	No	Yes	No	No	Yes	No
HPS Gastrointestinal & Zoonoses	Yes	No	Yes	Yes	Yes	No	No
Human Animal Infection and Risks Surveillance Group (HAIRS)	Yes	No	Yes	Yes	No	No	Yes
INFOSAN	Yes	Yes	Yes	Yes	Yes	No	No
INPP AZ (Pan American Institute for food protection and zoonoses)	Yes?	-	-	-	-	-	-
Massachusetts Statewide Zoonotic Disease Surveillance System	Yes	No	Yes	Yes	No	Yes	No
MEdiSys	Yes	Yes	Yes	Yes	No	No	Yes
MZCP WHO	Yes	Yes	Yes	Yes	No	No	Yes
National Companion Animal Surveillance System (NCASP)	Yes	No	Yes	Yes	No	Yes	No
National Electronic Disease Surveillance System (NEDSS)	Yes	No	No	Yes	Yes	No	No
National Zoonoses Committee of Ireland	No	-	-	-	-	-	-
National Zoonotic Infectious Diseases Surveillance AVMA	No	-	-	-	-		-

System Identified	Ongoing Surveillance?	International?	Zoonoses?	Multiple Pathogens?	Human Only?	Animal Only?	Animal & Human?
Netherlands Institute for Scientific Information Services	No	-	-	-	-	-	-
OIE Terrestrial Animal Health Code	Yes	Yes	Yes	Yes	No	Yes	No
PREDICT	Yes	Yes	Yes	Yes	No	Unclear?	Unclear?
ProMED Mail	Yes	Yes	Yes	Yes	No	No	Yes
RSVP−A	Yes?	No	Yes	Yes	No	Yes	No
SIRVETA	Unclear	-	-	-	-	-	-
Swiss Zoonoses Report/ZDU	Yes	No	Yes	Yes	No	No	Yes
TESSy (The European Surveillance System)	Yes	Yes	Yes	Yes	Yes	No	No
US State Vet System	Unclear	-	-	-	-	-	-
VetPAD	Yes	No	Yes	Yes	No	Yes	No
WAHID	Yes	Yes	Yes	Yes	No	Yes	No
WHO GAR	Yes	Yes	Yes	Yes	Yes	No	No
WHO HealthMapper & Global Health Atlas	Yes	Yes	Yes	Yes	Yes	No	No
Wildlife Health Monitoring Network/Wildlife Disease Information Node/WISDOM	Yes	No	Yes	Yes	No	Yes	No

Appendix C

Surveillance System Summaries

Table C.1: BioCaster System Summary

System Name	BioCaster
Purpose	BioCaster is a public health surveillance system that provides an early warning monitoring station for epidemic and environmental diseases (human, animal and plant)
Location/Coverage	Global with a priority for Asia-Pacific languages and health hazards
Setting	The BioCaster system has two major components: a web/-database server and a backend cluster computer equipped with a variety of ontology-based text mining algorithms which continuously scan hundreds of RSS newsfeeds from local and national news providers
Population	Humans and animals (zoonoses)
Year started	2006
Organisations involved	National Institute of Informatics, National Institute of Infectious Diseases and National Institute of Genetics, Okayama University, Vietnamese National University at Ho Chi Minh City and Kasetsart University
Syndromes and/or pathogens/diseases under surveillance	Infectious disease outbreaks
Single/Multiple	Multiple
Data collection	Aggregating online news reports and processing them automatically, using human language technology, to spot unusual trends
Data handling and analysis	The system, which continuously analyses documents reported from over 1700 RSS feeds, consists of four main stages: topic classification, named entity recognition (NER), disease/location detection and event recognition
Output/response	The text mining system has a detailed knowledge about the important concepts such as diseases, pathogens, symptoms, people, places, drugs etc allowing semantic indexing of relevant parts of news articles and classifies them for topical relevance and plots them onto a Google map using geocoded information. Higher order event analysis is used to detect more precisely specified warning signals that can then be notified to registered users via email alert
Animal/Human/Both	Both
Funding	National Institute of Informatics (NII) and the Japan Science and Technology Agency's PRESTO fund
Cost to user	Web access free and free email alerts to registered users

Table C.2: European Food Safety Authority (EFSA) Zoonoses Unit System Summary

System Name	European Food Safety Authority (EFSA) Zoonoses Unit
Purpose	To provide information to support risk managers in taking effective and timely decisions related to protection of humans from the zoonotic infections and also to provide information for risk assessors
Location/Coverage	Europe
Setting	The Unit is assisted by the Task Force on Zoonoses Data Collection, which comprises of representatives of Member States, other reporting countries as well as WHO and OIE
Population	Humans and animals (zoonoses only)
Year started	Not given
Organisations involved	EU Member States
Syndromes and/or pathogens/diseases under surveillance	Zoonoses
Single/Multiple	Multiple
Data collection	The Member States and some other reporting countries submit each year data on zoonoses, zoonotic agents, antimicrobial resistance, microbiological contaminants and food-borne outbreaks to EFSA and European Centre for Disease Prevention and Control (ECDC)
Data handling and analysis	The Unit on Zoonoses Data Collection (Zoonoses) collects and analyses data on occurrence of zoonoses, zoonotic agents in food, feed and animals as well food-borne outbreaks in the EU. In addition it gathers data on antimicrobial resistance in certain zoonotic agents and occurrence of microbiological contaminants
Output/response	Prepare risk assessments in response to Commission mandates and work undertaken on EFSAs own initiative; support the re-evaluation of authorised substances, such as food additives and flavourings; support the development of guidance for risk assessment and publishes annual Community Summary Reports based on collected data
Animal/Human/Both	Animals and zoonoses in humans
Funding	European Union
Cost to user	Free

Table C.3: EpiSPIDER System Summary

System Name	EpiSPIDER
Purpose	The EpiSPIDER project is designed to serve as a visualisation supplement to the ProMED-mail reports (See below) by displaying topic intensity information on a map. The topic and location information are also converted into RSS feeds
Location/Coverage	Global
Setting	Each news report that has location information is linked to relevant demographic- and health-specific information (e.g., population, per capita gross domestic product, public health expenditure, and physicians/1,000 population) providing different contexts for viewing emerging infectious disease information. Context-sensitive links to recent and relevant scientific literature for each ProMED-mail report topic are also provided
Population	Humans and animals
Year started	2006
Organisations involved	ProMED-mail, Google Earth
Syndromes and/or pathogens/diseases under surveillance	Combines data-mining for emerging infectious disease content with information from other Internet sites such as the Global Disaster Alert Coordinating System (GDACS) website
Single/Multiple	Multiple
Data collection	Natural language processing is used to transform free-text content into structured information that can be stored in a relational database. Location names are parsed from these reports and geo-referenced using the geo-referencing services of Yahoo Maps
Data handling and analysis	Extracted information is automatically transformed into other formats, e.g., RSS, keyhole markup language, and JavaScript object notation (JSON), a human-readable format for representing simple data structures
Output/response	Enabling faceted browsing of information by using scatter plots, Google Maps, and timelines - by the semantic linking of ProMED-mail content to country information and redistribution of structured data to services that can consume them
Animal/Human/Both	Both
Funding	Information not available
Cost to user	Information not available

Table C.4: Global Disease Detection Program (GDD) System Summary

System Name	Global Disease Detection Program (GDD)
Purpose	GDD is Centres for Disease Control and Prevention (CDC) principal and most visible program for developing and strengthening global public health capacity to rapidly identify and contain disease threats from around the world. The program comprises both field-based and CDC headquarters components
Location/Coverage	Global
Setting	GDD monitors and evaluates capabilities and progress on a quarterly basis using a framework that includes both quantitative and qualitative information on five key activities including the "Strengthening of surveillance systems capable of detecting, assessing, and monitoring the occurrence and public health significance of infectious disease threats"
Population	Humans and animals
Year started	2004
Organisations involved	The GDD Regional Centers work closely with host countries and regional partners, other headquarter-based components also play a significant role in working with other international organisations such as WHO and GOARN, other U.S. government agencies, and other partners
Syndromes and/or pathogens/diseases under surveillance	Identification and response to a wide range of emerging infections (including respiratory syndromes, diarrhoeal diseases, food-borne illnesses, zoonotic diseases, and others) through integrated disease surveillance, prevention, and control activities
Single/Multiple	Multiple
Data collection	The GDD Operations Center is an innovative epidemic intelligence and response operations unit located at CDC headquarters. It uses nontraditional surveillance methods to provide early warning about international disease threats so CDC can respond rapidly to protect public health in the United States and the global community
Data handling and analysis	GDD Regional Centers follow a step-wise approach to develop sophisticated surveillance capacity. This begins with an accurate case definition and is followed by population-based surveillance and more sophisticated lab testing. The objective is to accurately define disease burden to influence public health policy that assists in decreasing morbidity and mortality
Output/response	Through its surveillance function, the GDD Operations Center is often the first to alert CDC U.S. based programs or CDC international staff about a disease outbreak. A key source of information about disease events is internet-based media reports, scanned for key words in over 40 languages. To facilitate rapid response, the GDD Operations Center has an outbreak fund to support travel, supplies, and shipping specimens
Animal/Human/Both	Both
Funding	Funded by CDC
Cost to user	No published costs

Table C.5: Global Emerging Infections Surveillance and Response System (GEIS) System Summary

System Name	Global Emerging Infections Surveillance and Response System (GEIS)
Purpose	To be a scientifically credible and recognised worldwide surveillance system for emerging infections, fully integrating a global network of laboratory capabilities with a comprehensive US Department of Defense (DoD) health surveillance system
Location/Coverage	Global
Setting	To develop, implement, support, and evaluate an integrated global emerging infections surveillance and response system that supports the Armed Forces Health Surveillance Centre (AFHSC) and contributes to force health protection in U.S. Forces, the Military Health System (MHS), and the global public health community
Population	Humans and animals for zoonoses
Year started	1997
Organisations involved	29 US forces and national research institutions worldwide (19 Americas, 6 Australasia, 2 Europe, and 2 Africa)
Syndromes and/or pathogens/diseases under surveillance	Priority Surveillance Pillars: Respiratory Infection; Gastrointestinal Infection; Febrile and Vector-borne Infection; Antimicrobial Resistance; Sexually Transmitted Infection
Single/Multiple	Multiple
Data collection	Laboratory-based surveillance is augmented by significant epidemiologic training and preparedness initiatives
Data handling and analysis	Laboratory surveillance system is complimented by the DoD electronic health care encounter datasets
Output/response	The goals of GEIS surveillance are 1) to identify and characterise antigenically diverse strains, that affect DoD beneficiary populations and threaten global public health and 2) to collaborate with relevant organisations such as the Centers for Disease Control and Prevention (CDC), U.S. Food and Drug Administration (FDA), and the WHO to develop vaccines and other effective public health treatments and interventions. Laboratory-based surveillance is augmented by significant epidemiologic training and preparedness initiatives
Animal/Human/Both	Both
Funding	Funds from U.S. Congress and US DoD budgets
Cost to user	No published charges

Table C.6: Global Foodborne Infections Network (GFN) System Summary

System Name	Global Foodborne Infections Network (GFN)
Purpose	To promote integrated, laboratory-based surveillance and foster intersectoral collaboration among human health, veterinary and food-related disciplines through training courses and activities around the world
Location/Coverage	Global
Setting	The objective of the network is to strengthen and enhance the capacities of national and regional laboratories in the surveillance of Salmonella, the other major foodborne pathogens and antimicrobial resistance in Salmonella and Campylobacter from humans, food and animals through the programme activities
Population	Humans and animals
Year started	2000
Organisations involved	GFN is a collaborative project of the World Health Organization (WHO), the Danish National Food Institute (DTU Food), the Centers for Disease Control and Prevention (CDC), the Institut Pasteur, the Public Health Agency of Canada, Utrecht University, European Centre for Disease Prevention and Control (ECDC), OzFoodNet, PulseNet International and the National Institute of Public Health, Japan
Syndromes and/or pathogens/diseases under surveillance	Salmonella and other major foodborne pathogens and antimicrobial resistance in Salmonella and Campylobacter from humans, food and animals
Single/Multiple	Multiple
Data collection	The programme promotes integrated, laboratory-based surveillance and outbreak detection and response, and fosters intersectoral collaboration and communication among microbiologists and epidemiologists in human health, veterinary, and food-related disciplines. There are currently more than 1500 individual members of the GFN from National Reference laboratories and other national and regional institutes in 177 Member States and territories
Data handling and analysis	To date, more than 80 countries have provided data to the Country Databank on around 1.5 million human isolates and 360 000 isolates from nonhuman sources to help provide a global overview of the epidemiology of Salmonella
Output/response	The Global Foodborne Infections Network has six main programme components: international training activities, the External Quality Assurance System (EQAS), the WHO Global Salmonella Country Databank, focused regional and national projects, reference services and communication
Animal/Human/Both	Both
Funding	Funded by WHO and partner institutions
Cost to user	No published cost

Table C.7: The Global Early Warning and Response System for Major Animal Diseases, including Zoonoses (GLEWS) System Summary

System Name	The Global Early Warning and Response System for Major Animal Diseases, including Zoonoses (GLEWS)
Purpose	GLEWS is a joint system that builds on the added value of combining and coordinating the alert and response mechanisms of OIE, FAO and WHO for the international community and stakeholders to assist in prediction, prevention and control of animal disease threats, including zoonoses, through sharing of information, epidemiological analysis and joint field missions to assess and control the outbreak, whenever needed
Location/Coverage	Global
Setting	The overall aim of GLEWS is to improve the early warning and response capacity to animal disease threats of the three sister organisations for the benefit of the international community
Population	Global animal and human populations
Year started	2006
Organisations involved	OIE, WHO & FAO
Syndromes and/or pathogens/diseases under surveillance	6 non-zoonotic and 19 zoonotic diseases accorded priority with 4 (CBPP, FMD, RVF, Sheep Pox) for which trend analysis and forecasting will be emphasised
Single/Multiple	Multiple
Data collection	The three sister organisations use their channels and contacts within their respective mandates to track information on disease outbreaks. Information gathered will be fed into a GLEWS electronic platform (yet to be developed, pending funding). In this platform information will be further analysed, monitored and/or sent out as Early Warning Messages
Data handling and analysis	Specific analysis and modelling of trends will be carried out utilising selected OIE and FAO Collaborating Centres, OIE and FAO Laboratories and where appropriate WHO Collaborating Centres and Laboratories. The verification process involves the use of various sources of information and networks that need to be cross-checked and validated (see below for detail)
Output/response	Until the GLEWS information platform has been developed, the information is communicated via e-mail using a standard reporting format for initial reports to the GLEWS focal points A GLEWS Emergency Response will only be necessary, if there is clear indication for a joint onsite assessment or intervention mission
Animal/Human/Both	Primarily Animal Health but uses human health as a sentinel system
Funding	The basic minimum financial needs take into account the fact that the three organisations have already existing early warning and response systems and will be used to implement the activities in relation with animal health information sharing, epidemiological analysis studies between the three sister organisations as well complementing their existing response systems for a more rapid and a better coordinated international response to animal disease emergencies. (WHO will be involved in the field of zoonoses)

Table C.8: Global Outbreak Alert and Response Network (GOARN) System Summary

System Name	Global Outbreak Alert and Response Network (GOARN)
Purpose	The GOARN is a technical collaboration of existing institutions and networks to pool human and technical resources for the rapid identification, confirmation and response to outbreaks of international importance
Location/Coverage	Global
Setting	The Network provides an operational framework to link public health expertise and skill to keep the international community constantly alert to the threat of outbreaks and ready to respond
Population	Humans and animals
Year started	April 2000
Organisations involved	With WHO coordination the network includes scientific institutions in Member States, regional technical networks, United Nations organisations, the Red Cross and international humanitarian non-governmental organisations. Participation is open to technical institutions, networks and organisations that have the capacity to contribute to international outbreak alert and response
Syndromes and/or pathogens/diseases under surveillance	GOARN is directed towards promoting standard operating procedures [inclusive of surveillance initiatives], coordination and activation of international support to deal with epidemic-prone and emerging disease outbreaks of international importance
Single/Multiple	Multiple
Data collection	Co-ordination only
Data handling and analysis	Co-ordination only
Output/response	The Global Outbreak Alert and Response Network focuses the technical and operational resources of partner institutions and networks to promote collaborative effort
Animal/Human/Both	Both
Funding	WHO coordinates international outbreak response using resources from the network. WHO also provides a secretarial service for the network (e.g. employment of project manager, support for the Steering Committee and structures) as part of its Alert and Response Operations within CSR

Table C.9: The Global Public Health Intelligence Network (GPHIN) System Summary

System Name	The Global Public Health Intelligence Network (GPHIN)
Purpose	GPHIN is a secure Internet-based "early warning" system that gathers and disseminates preliminary reports of global public health significance on a near "real-time" basis
Location/Coverage	Global
Setting	The system monitors global media sources such as news wires and web sites to capture public health information of interest
Population	Humans and animals
Year started	Prototype launched July 2000 and an upgraded multi-lingual system launched November 2004
Organisations involved	GPHIN is managed by the Public Health Agency of Canadas Centre for Emergency Preparedness and Response (CEPR). Information from GPHIN is provided to the WHO, international governments and non-governmental organisations
Syndromes and/or pathogens/diseases under surveillance	GPHIN covers a broad scope of public health issues. It tracks events such as infectious disease outbreaks, contaminated food and water, bio-terrorism, chemical and radioactive incidents, natural disasters and issues related to the safety of products, drugs and medical devices
Single/Multiple	Multiple
Data collection	The GPHIN software "pulls" relevant articles every 15 minutes from newsfeed aggregators based on established search syntaxes
Data handling and analysis	The captured articles are filtered and categorised into one or more of GPHINs 8 taxonomy categories that include animal and human diseases
Output/response	Articles with a relevancy score above a certain threshold are automatically 'published' to the GPHIN database. Articles that are deemed of immediate concern by the GPHIN analysts are immediately sent to users by email as 'alerts'. Users may review the latest list of published articles or they can further filter the list with the use of a query function to view specific articles
Animal/Human/Both	Both
Funding	Managed by Canadas Centre for Emergency Preparedness and Response (CEPR) with some income earned through a given scale of yearly subscription rates

Table C.10: HealthMap System Summary

System Name	HealthMap
Purpose	A freely accessible, automated electronic information system for monitoring, organising, and visualising reports of global disease outbreaks according to geography, time, and infectious disease agent
Location/Coverage	Global
Setting	An automated system for querying, filtering, integrating and visualising unstructured reports on disease outbreaks Web site integrates outbreak data of varying reliability, ranging from news sources (such as Google News) to curated personal accounts (such as ProMED) to validated official alerts (such as World Health Organization)
Population	Humans and Animals
Year started	2006
Organisations involved	Google.Org , National Institutes of Health Research / National Library Of Medicine, Centers For Disease Control And Prevention, Canadian Institutes of Health Research, International Society for Infectious Diseases / ProMED, Health and Human Services , Flu.Gov, International Society for Disease Surveillance, International Society for Travel Medicine, Geosentinel, New England Journal of Medicine, Wildlife Conservation Society
Syndromes and/or pathogens/diseases under surveillance	Emerging infectious disease outbreaks
Single/Multiple	Multiple
Data collection	An automated text processing system is used to integrate outbreak data of varying reliability, ranging from news sources to curated personal accounts to validated official alerts
Data handling and analysis	Through an automated system for querying, filtering, integrating and visualising unstructured reports on disease outbreaks the data is aggregated by disease and displayed by location
Output/response	Maps showing location of disease outbreaks with three other outputs: Flu.Gov - an interactive map with comprehensive real-time information (both official and unofficial) on seasonal influenza and H1N1 pandemic. MedWatcher Designed to engage users in issues of drug safety and real-time pharmacovigilance. OutbreakMD a data-collecting system designed primarily for health professionals located in areas where Internet may be scarce or unavailable
Animal/Human/Both	Both
Funding	From partners and collaborators as listed above
Cost to user	Free

Table C.11: MedISys System Summary

System Name	MedISys - Medical Information System (formerly Medical Intelligence System)
Purpose	To reinforce the network for surveillance of communicable diseases and the early detection of bioterrorism activities
Location/Coverage	Global
Setting	An internet monitoring and analysis system developed at the Joint Research Centre, Ispra, Italy in collaboration with EC Directorate General SANCO. It uses online information sources to rapidly detect, track and assess threats to the public health so that advance warning can be given
Population	Humans and Animals
Year started	Not given
Organisations involved	The Health Threat Unit at Directorate General Health and Consumer Affairs of the EC in collaboration with Joint Research Centre, Ispra, Italy
Syndromes and/or pathogens/diseases under surveillance	Outbreaks of communicable diseases, risks linked to chemical and nuclear accidents and terrorist attacks, i.e. events that could have a widespread impact on the health of the European Community
Single/Multiple	Multiple
Data collection	Processes over 20,000 articles per day from about 250 specialist medical sites and over 4,000 sites of approximately 1,600 news sources (news and medical sites) in 45 languages
Data handling and analysis	Using text mining, event extraction with the Pattern-based Understanding and Learning System (PULS, developed by the University of Helsinki), articles collected are grouped into hundreds of categories (e.g. diseases, symptoms, chemical agents, etc.) based on pre-defined keyword combinations
Output/response	On the public site http://medusa.jrc.it/, displays articles with interest to Public Health, grouped by disease or disease type. Specialist Public Health organisations can request access to the restricted site, which offers more functionality, more categories and more news sources
Animal/Human/Both	Both
Funding	European Commission
Cost to user	Charges for specialist access but costs not given

Table C.12: Mediterranean Zoonoses Control Programme (MZCP) System Summary

System Name	Mediterranean Zoonoses Control Programme (MZCP)
Purpose	An interregional (Mediterranean and Middle East) programme on zoonoses and foodborne diseases prevention, surveillance and control through intersectoral collaboration and coordination
Location/Coverage	The participating countries are Cyprus, Egypt, Greece, Lebanon, Kuwait, Portugal, Saudi Arabia, Spain, Syrian Arab Republic and Turkey; countries associated with the Programme are Algeria, Italy, Jordan, Malta, Morocco, Tunisia and Yemen
Setting	The main objectives of the MZCP are promoting programmes for the prevention, surveillance and control of zoonoses and related foodborne diseases; strengthening collaboration between veterinary and public health services; implementing training activities; promoting veterinary public health activities and public health education; and fostering collaboration among Member Countries
Population	Humans and animals
Year started	1978
Organisations involved	The MZCP is guided by WHO/Headquarters, Geneva, closely collaborates with the WHO-Regional Office for the Eastern Mediterranean, Cairo, Egypt, and a network of specialised WHO & MZCP-Collaborating Institutions as well as with FAO and OIE
Syndromes and/or pathogens/diseases under surveillance	Zoonoses of major interest in the Mediterranean and Middle East Regions -Brucellosis, Cystic Echinococcosis, Leishmaniasis, Rabies and Foodborne Zoonotic Diseases
Single/Multiple	Multiple
Data collection	Surveillance networks covering MZCP countries
Data handling and analysis	By national animal and human health services and the Mediterranean Zoonoses Control Centre (MZCC), located in Athens, Greece
Output/response	The development of human and technical resources for rapid response to epidemics -information technology, epidemiology, food safety tools and regulations inclusive of intercountry training courses on high priority regional subjects and national training courses on subjects selected by the Member Countries, according to their own priorities
Animal/Human/Both	Both
Funding	The Programme depends on the annual contributions of US$ 20,000 from its participating States and on the contributions in kind (technical, scientific etc.) of its collaborating institutions
Cost to user	All services delivered are free of charge to the Member States

Table C.13: ProMED System Summary

System Name	ProMED & ProMED-Mail (PMM)
Purpose	An Internet-based reporting system dedicated to rapid global dissemination of information on outbreaks of infectious diseases and acute exposures to toxins that affect human health, including those in animals and in plants grown for food or animal feed
Location/Coverage	Global
Setting	A central purpose of ProMED-Mail is to promote communication amongst the international infectious disease community, including scientists, physicians, epidemiologists, public health professionals, and others interested in infectious diseases on a global scale
Population	Humans and animals
Year started	1994
Organisations involved	International Society for Infectious Diseases (ISID), a non-profit professional organisation with 20,000 members worldwide. Web services provided by Oracle Corporation and E-mail services by the Harvard School of Public Health
Syndromes and/or pathogens/diseases under surveillance	Outbreaks of emerging and re-emerging diseases
Single/Multiple	Multiple
Data collection	Sources of information include media reports, official reports, online summaries, local observers, and others. Reports are often contributed by ProMED-Mail subscribers
Data handling and analysis	A team of expert human, plant, and animal disease moderators screen, review, and investigate reports before posting to the network
Output/response	The moderator edits selected pieces for content, provides pertinent references (both from prior ProMED-Mail reports and from the scientific literature), and adds a brief commentary. Reports are distributed by email to direct subscribers and posted immediately on the ProMED-Mail web site. ProMED-Mail currently reaches over 40,000 subscribers in at least 185 countries
Animal/Human/Both	Both
Funding	Funding from Google.org, the Gates Foundation, the Rockefeller Foundation, the Oracle Corporation, the Nuclear Threat Initiative
Cost to user	Free

Bibliography

Allela, L., Boury, O., Pouillot, R., Délicat, A., Yaba, P., Kumulungui, B., Rouquet, P., Gonzalez, J.-P., Leroy, E. M., 2005. Ebola virus antibody prevalence in dogs and human risk. Emerging Infectious Diseases 11 (3), 385–390.

Arnesen, T., Nord, E., 1999. The value of DALY life: problems with ethics and validity of disability adjusted life years. British Medical Journal 319 (7222), 1423–1425.

Austgen, L. E., Bowen, R. A., Bunning, M. L., Davis, B. S., Mitchell, C. J., Chang, G.-J. J., 2004. Experimental infection of cats and dogs with West Nile virus. Emerging Infectious Diseases 10 (1), 82–86.

Azhar, M., Lubis, A. S., Siregar, E. S., Alders, R. G., Brum, E., McGrane, J., Morgan, I., Roeder, P., 2010. Participatory disease surveillance and response in Indonesia: strengthening veterinary services and empowering communities to prevent and control highly pathogenic avian influenza. Avian Diseases 54 (1 Suppl), 749–753.

Babin, S., 2010. Using syndromic surveillance systems to detect pneumonic plague. Epidemiology and Infection 138, 1–8.

Baker, M. G., Easther, S., Wilson, N., 2010. A surveillance sector review applied to infectious diseases at a country level. BMC Public Health 10, 332.

Bett, B., Jost, C., Allport, R., Mariner, J., 2009. Using participatory epidemiological techniques to estimate the relative incidence and impact on livelihoods of livestock diseases amongst nomadic pastoralists in Turkana South District, Kenya. Preventive Veterinary Medicine 90 (3-4), 194–203.

Beutels, P., Edmunds, W. J., Smith, R. D., 2008. Partially wrong? Partial equilibrium and the economic analysis of public health emergencies of international concern. Health Economics 17 (11), 1317–1322.

Bravata, D. M., McDonald, K. M., Smith, W. M., Rydzak, C., Szeto, H., Buckeridge, D. L., Haberland, C., Owens, D. K., 2004. Systematic review: surveillance systems for early detection of bioterrorism-related diseases. Annals of Internal Medicine 140 (11), 910–922.

Breiman, R. F., Nasidi, A., Katz, M. A., Njenga, M. K., Vertefeuille, J., 2007. Preparedness for highly pathogenic avian influenza pandemic in Africa. Emerging Infectious Diseases 13 (10), 1453–1458.

Brownstein, J. S., Freifeld, C. C., Madoff, L. C., 2009. Digital disease detection–harnessing the web for public health surveillance. New England Journal of Medicine 360 (21), 2153–5, 2157.

Brownstein, J. S., Freifeld, C. C., Reis, B. Y., Mandl, K. D., 2008. Surveillance sans frontires: Internet-based emerging infectious disease intelligence and the healthmap project. PLoS Medicine 5 (7), e151.

Budke, C. M., Jiamin, Q., Qian, W., Torgerson, P. R., 2005. Economic effects of echinococcosis in a disease-endemic region of the Tibetan Plateau. American Journal of Tropical Medicine and Hygiene 73 (1), 2–10.

Burns, K., 2006. Watching for signs, symptoms of disease. Journal of the American Veterinary Medical Association 228, 1846–1848.

Carabin, H., Budke, C. M., Cowan, L. D., Willingham, A. L., Torgerson, P. R., 2005. Methods for assessing the burden of parasitic zoonoses: echinococcosis and cysticercosis. Trends in Parasitology 21 (7), 327–333.

Cash, R. A., Narasimhan, V., 2000. Impediments to global surveillance of infectious diseases: consequences of open reporting in a global economy. Bulletin of the World Health Organization 78 (11), 1358–1367.

CDC, 1988. Guidelines for evaluating surveillance systems. Morbidity and Mortality Weekly Report (MMWR) 37 (S-5), 1–18.

CDC, 2001. Updated guidelines for evaluating surveillance systems. Morbidity and Mortality Weekly Report (MMWR) 10 (RR-13), 1–38.

CDC, 2004. Framework for evaluating public health surveillance systems for early detection of outbreaks. Morbidity and Mortality Weekly Report (MMWR) 53 (RR-05), 1–11.

CDC, 2008. Manual for the Surveillance of Vaccine-Preventable Diseases. National Center for Immunization and Respiratory Diseases Centers for Disease Control and Prevention Department of Health and Human Services, 4th Edition.
URL `http://www.cdc.gov/vaccines/pubs/surv-manual/`

Centers for Epidemiology, Animal Health (CEAH), 2006. Standards for the key components of a surveillance system. In: Surveillance and Data Standards for USDA/APHIS/Veterinary Services.
URL `http://www.aphis.usda.gov/vs/nahss/docs/surveillance_standards_chapter1_planning_surveillance_systems_v1.0_july_2006.pdf`

Chan, E. H., Brewer, T. F., Madoff, L. C., Pollack, M. P., Sonricker, A. L., Keller, M., Freifeld, C. C., Blench, M., Mawudeku, A., Brownstein, J. S., 2010. Global capacity for emerging infectious disease detection. Proceedings of the National Academy of Sciences of the United States of America 107 (50), 21701–21706.

Chomel, B. B., 2003. Control and prevention of emerging zoonoses. Journal of Veterinary Medical Education 30 (2), 145–147.

Civic Consulting, 2009. Cost of National Prevention Systems for Animal Diseases and Zoonoses in Developing and Transition Countries.
URL http://www.oie.int/eng/OIE-WB_Conference_1007/en_Global_Animal_Health_Initiative.htm

Cleaveland, S., Laurenson, M. K., Taylor, L. H., 2001. Diseases of humans and their domestic mammals: pathogen characteristics, host range and the risk of emergence. Philosophical Transactions of the Royal Society of London Series B-Biological Sciences 356 (1411), 991–999.

Cleaveland, S., Meslin, F. X., Breiman, R., 2006. Dogs can play useful role as sentinel hosts for disease. Nature 440 (7084), 605–605.

Dailey, L., Watkins, R. E., Plant, A. J., 2007. Timeliness of data sources used for influenza surveillance. Journal of the American Medical Informatics Association 14 (5), 626–631.

Danuser, J., Aubert, U., 2007. Basic principles of monitoring for zoonoses. In: Swiss Zoonosis Report 2007.
URL http://www.bvet.admin.ch/dokumentation/00327/02466/02512/index.html?lang=en

Daszak, P., Bogich, T., Hosseini, P., Olival, K., Zambrana-Torrelio, C., Karesh, B., Mazet, J., Morse, S., 2010. Wildlife & emerging diseases: Drivers, maps and the road ahead. In: International Meeting on Emerging Diseases (IMED).
URL http://ww2.isid.org/Downloads/IMED2011_Presentations/IMED2011_Daszak.pdf

Drummond, M., Sculpher, M., Torrance, G., O'Brien, B., Stoddart, G., 1997. Methods for the Economic Evaluation of Health Care Programmes, 3rd Edition. Oxford University Press.

Earth Institute, 2010. Barriers and Gaps Affecting mHealth in Low and Middle Income Countries: A Policy White Paper. mHealth Alliance, Washington, D.C.
URL cghed.ei.columbia.edu/sitefiles/file/mHealthBarriersWhitePaperFINAL.pdf

Eidson, M., Schmit, K., Hagiwara, Y., Anand, M., Backenson, P. B., Gotham, I., Kramer, L., 2005. Dead crow density and West Nile virus monitoring, New York. Emerging Infectious Diseases 11 (9), 1370–1375.

FAO, 2002. Improved Animal Health for Poverty Reduction and Sustainable Livelihoods. FAO animal production and health paper 153. Food and Agriculture Organization of the United Nations (FAO).
URL http://www.fao.org/docrep/005/y3542e/y3542e00.htm

FAO, OIE, WHO, 2008. The FAO-OIE-WHO Collaboration. Sharing responsibilities and coordinating global activities to address health risks at the animal-human-ecosystems interfaces. A Tripartite Concept Note. Food and Agriculture Organization of the United Nations (FAO) and World Organisation for Animal Health (OIE) and World Health Organization (WHO.
URL `http://www.fao.org/docrep/012/ak736e/ak736e00.pdf`

Freifeld, C. C., Chunara, R., Mekaru, S. R., Chan, E. H., Kass-Hout, T., Iacucci, A. A., Brownstein, J. S., 2010. Participatory epidemiology: use of mobile phones for community-based health reporting. PLoS Medicine 7 (12), e1000376.

GAO, 2001. Global Health: Challenges in improving infectious disease surveillance systems. United States General Accounting Office (GAO).
URL `http://www.gao.gov/new.items/d01722.pdf`

Giese, M., Harder, T. C., Teifke, J. P., Klopfleisch, R., Breithaupt, A., Mettenleiter, T. C., Vahlenkamp, T. W., 2008. Experimental infection and natural contact exposure of dogs with avian influenza virus (H5N1). Emerging Infectious Diseases 14, 308–310.

Ginsberg, J., Mohebbi, M. H., Patel, R. S., Brammer, L., Smolinski, M. S., Brilliant, L., 2009. Detecting influenza epidemics using search engine query data. Nature 457 (7232), 1012–1014.

Glickman, L. T., Moore, G. E., Glickman, N. W., Caldanaro, R. J., Aucoin, D., Lewis, H. B., 2006. Purdue university-banfield national companion animal surveillance program for emerging and zoonotic diseases. Vector Borne and Zoonotic Diseases 6 (1), 14–23.

Guasticchi, G., Rossi, P. G., Lori, G., Genio, S., Biagetti, F., Gabriele, S., Pezzotti, P., Borgia, P., 2009. Syndromic surveillance: sensitivity and positive predictive value of the case definitions. Epidemiology and Infection 137 (5), 662–671.

Halliday, J. E. B., 2010. Animal sentinel surveillance: Evaluating domestic dogs as sentinels for zoonotic pathogen surveillance. Ph.D. thesis, University of Edinburgh.

Halliday, J. E. B., Meredith, A. L., Knobel, D. L., Shaw, D. J., Bronsvoort, B., Cleaveland, S., 2007. A framework for evaluating animals as sentinels for infectious disease surveillance. Journal of the Royal Society Interface 4, 973–984.

Henning, K. J., 2004. What is syndromic surveillance? Morbidity and Mortality Weekly Report (MMWR) 53 Suppl, 5–11.

Hitchcock, P., Chamberlain, A., Wagoner, M. V., Inglesby, T. V., O'Toole, T., Sep 2007. Challenges to global surveillance and response to infectious disease outbreaks of international importance. Biosecurity and Bioterrorism: Biodefense, Strategy, Practice and Science 5 (3), 206–227.

Hoinville, L., Ellis-Iversen, J., Vink, D., Watson, E., Snow, L., Gibbens, J., 2009. Discussing the development and application of methods for effective surveillance in

livestock populations: Report of a workshop held prior to the ISVEE conference, Durban, South Africa, August 2009.
URL `http://www.defra.gov.uk/vla/reports/docs/rep_pres_isvee.pdf`

HSCC, 2004. Framework and Tools for Evaluating Health Surveillance Systems. Health Surveillance Coordinating Committee (HSCC) Population and Public Health Brance, Health Canada.
URL `http://www.phac-aspc.gc.ca/php-psp/hssef-eng.php`

IOM, 2007. Global Infectious Disease Survillance and Detection: Assessing the Challenges - Finding Solutions. Workshop Summary. The National Academies Press.

IOM, NRC, 2009. Sustaining Global Surveillance and Response to Emerging Zoonotic Diseases. The National Academies Press.

Irvin, C. B., Nouhan, P. P., Rice, K., 2003. Syndromic analysis of computerized emergency department patients' chief complaints: an opportunity for bioterrorism and influenza surveillance. Annals of Emergency Medicine 41 (4), 447–452.

ITU, 2011. The world in 2010: Facts and figures.
URL `http://www.itu.int/ITU-D/ict/statistics/index.html`

Jajosky, R. A., Groseclose, S. L., Jul 2004. Evaluation of reporting timeliness of public health surveillance systems for infectious diseases. BMC Public Health 4, 29.

John, K., Kazwala, R., Mfinanga, G. S., 2008. Knowledge of causes, clinical features and diagnosis of common zoonoses among medical practitioners in Tanzania. BMC Infectious Diseases 8, 162.

Johnson, G. D., Eidson, M., Schmit, K., Ellis, A., Kulldorff, M., 2006. Geographic prediction of human onset of West Nile virus using dead crow clusters: an evaluation of year 2002 data in New York State. American Journal of Epidemiology 163 (2), 171–180.

Jones, K. E., Patel, N. G., Levy, M. A., Storeygard, A., Balk, D., Gittleman, J. L., Daszak, P., 2008. Global trends in emerging infectious diseases. Nature 451 (7181), 990–U4.

Jost, C. C., Mariner, J. C., Roeder, P. L., Sawitri, E., Macgregor-Skinner, G. J., 2007. Participatory epidemiology in disease surveillance and research. Revue Scientifique Et Technique-Office International Des Epizooties 26 (3), 537–549.

Jost, C. C., Nzietchueng, S., Kihu, S., Bett, B., Njogu, G., Swai, E. S., Mariner, J. C., 2010. Epidemiological assessment of the Rift Valley fever outbreak in Kenya and Tanzania in 2006 and 2007. American Journal of Tropical Medicine and Hygiene 83 (2 Suppl), 65–72.

Kahn, L. H., 2006. Confronting zoonoses, linking human and veterinary medicine. Emerging Infectious Diseases 12 (4), 556–561.

Kapiriri, L., Arnesen, T., Norheim, O. F., 2004. Is cost-effectiveness analysis preferred to severity of disease as the main guiding principle in priority setting in resource poor settings? the case of Uganda. Cost Effectiveness and Resource Allocation 2 (1), 1.

King, D. A., Peckham, C., Waage, J. K., Brownlie, J., Woolhouse, M. E. J., 2006. Epidemiology. infectious diseases: preparing for the future. Science 313 (5792), 1392–1393.

King, L. J., Marano, N., Hughes, J. M., 2004. New partnerships between animal health services and public health agencies. Revue Scientifique Et Technique-Office International Des Epizooties 23 (2), 717–725.

Knight-Jones, T. J. D., Hauser, R., Matthes, D., Strk, K. D. C., 2010. Evaluation of effectiveness and efficiency of wild bird surveillance for avian influenza. Veterinary Research 41 (4), 50.

Knobel, D. L., Cleaveland, S., Coleman, P. G., Fèvre, E. M., Meltzer, M. I., Miranda, M. E. G., Shaw, A., Zinsstag, J., Meslin, F. X., 2005. Re-evaluating the burden of rabies in Africa and Asia. Bulletin of the World Health Organization 83 (5), 360–368.

Koplan, J. P., 1985. Benefits, risks and costs of immunization programmes. Ciba Foundation Symposium 110, 55–68.

Kuiken, T., Leighton, F. A., Fouchier, R. A. M., LeDuc, J. W., Peiris, J. S. M., Schudel, A., Sthr, K., Osterhaus, A. D. M. E., 2005. Public health. pathogen surveillance in animals. Science 309 (5741), 1680–1681.

Laxminarayan, R., Malani, A., 2009. The right combination of carrots and sticks: Encouraging surveillance and reporting of emerging pandemics. Resources 173, 13–15.

Lembo, T., Hampson, K., Auty, H., Beesley, C. A., Bessell, P., Packer, C., Halliday, J., Fyumagwa, R., Hoare, R., Ernest, E., Mentzel, C., Mlengeya, T., Stamey, K., Wilkins, P. P., Cleaveland, S., 2011. Serologic surveillance of anthrax in the serengeti ecosystem, tanzania, 1996-2009. Emerging Infectious Diseases 17 (3), 387–394.

Lembo, T., Hampson, K., Kaare, M. T., Ernest, E., Knobel, D., Kazwala, R. R., Haydon, D. T., Cleaveland, S., 2010. The feasibility of canine rabies elimination in Africa: dispelling doubts with data. PLoS Neglected Tropical Animal Diseases 4 (2), e626.

Lester, R. T., Ritvo, P., Mills, E. J., Kariri, A., Karanja, S., Chung, M. H., Jack, W., Habyarimana, J., Sadatsafavi, M., Najafzadeh, M., Marra, C. A., Estambale, B., Ngugi, E., Ball, T. B., Thabane, L., Gelmon, L. J., Kimani, J., Ackers, M., Plummer, F. A., 2010. Effects of a mobile phone short message service on antiretroviral treatment adherence in Kenya (WelTel Kenya1): a randomised trial. Lancet 376 (9755), 1838–1845.

Lewis, M. D., Pavlin, J. A., Mansfield, J. L., O'Brien, S., Boomsma, L. G., Elbert, Y., Kelley, P. W., 2002. Disease outbreak detection system using syndromic data in the greater Washington DC area. American Journal of Preventive Medicine 23 (3), 180–186.

Loonsk, J. W., 2004. Biosense–a national initiative for early detection and quantification of public health emergencies. Morbidity and Mortality Weekly Report (MMWR) 53 Suppl, 53–55.

Mariner, J., Roeder, P. L., 2010. Use of participatory epidemiology in studies of the persistence of lineage 2 rinderpest virus in East Africa. The Veterinary Record 152, 641–647.

Marsden-Haug, N., Foster, V., Gould, P., Elbert, E., Wang, H., Pavlin, J., 2007. Code-based surveillance for influenzalike illness by international classification of diseases, ninth revision. Emerging Infectious Diseases 13, 207–216.

Maudlin, I., Eisler, M. C., Welburn, S. C., Sep 2009. Neglected and endemic zoonoses. Philosophical Transactions of the Royal Society of London Series B-Biological Sciences 364 (1530), 2777–2787.

McCluskey, B., 2003. Animal disease surveillance and survey systems: methods and applications. Iowa State Press, Ch. Use of sentinel herds in monitoring and surveillance systems, pp. 119–133.

Merianos, A., Peiris, M., 2005. International health regulations (2005). Lancet 366 (9493), 1249–1251.

Metre, D. C. V., Barkey, D. Q., Salman, M. D., Morley, P. S., 2009. Development of a syndromic surveillance system for detection of disease among livestock entering an auction market. Journal of the American Veterinary Medical Association 234 (5), 658–664.

Meynard, J.-B., Chaudet, H., Green, A. D., Jefferson, H. L., Texier, G., Webber, D., Dupuy, B., Boutin, J.-P., 2008. Proposal of a framework for evaluating military surveillance systems for early detection of outbreaks on duty areas. BMC Public Health 8, 146.

Molyneux, D., Hallaj, Z., Keusch, G. T., McManus, D. P., Ngowi, H., Cleaveland, S., Ramos-Jimenez, P., Gotuzzo, E., Kar, K., Sanchez, A., Garba, A., Carabin, H., Bassili, A., Chaignat, C. L., Meslin, F.-X., Abushama, H. M., Willingham, A. L., Kioy, D., 2011. Zoonoses and marginalised infectious diseases of poverty: where do we stand? Parasites and Vectors 4, 106.
URL `http://dx.doi.org/10.1186/1756-3305-4-106`

Molyneux, D. H., 2008. Combating the "other diseases" of mdg 6: changing the paradigm to achieve equity and poverty reduction? Transactions of the Royal Society of Tropical Medicine and Hygiene 102 (6), 509–519.

Monto, A. S., 2002. Epidemiology of viral respiratory infections. American Journal of Medicine 112 Suppl 6A, 4S–12S.

Morse, S. S., 1995. Factors in the emergence of infectious diseases. Emerging Infectious Diseases 1 (1), 7–15.

Mostashari, F., Kulldorff, M., Hartman, J. J., Miller, J. R., Kulasekera, V., 2003. Dead bird clusters as an early warning system for West Nile virus activity. Emerging Infectious Diseases 9 (6), 641–646.

Mtema, Z., Hampson, K., Russell, T., Prosper, C., Killeen, G., Burd, E., Murray-Smith, R., 2010. A case study on use of mobile computing technologies in health surveillance for developing countries. In: 12th International Conference on Human-Computer Interaction with Mobile Devices and Services, Mobile HCI.

Murphy, F. A., 1998. Emerging zoonoses. Emerging Infectious Diseases 4 (3), 429–435.

Murray, D. L., Kapke, C. A., Evermann, J. F., Fuller, T. K., 1999. Infectious disaese and the conservation of free-ranging large carnivores. Animal Conservation 2, 241–254.

Nayar, A., 2009. Emerging disease: Looking for trouble. Nature 462 (7274), 717–719.

Nicoll, A., Jones, J., Aavitsland, P., Giesecke, J., 2005. Proposed new international health regulations. British Medical Journal 330 (7487), 321–322.

Ohmit, S. E., Monto, A. S., 2006. Symptomatic predictors of influenza virus positivity in children during the influenza season. Clinical Infectious Diseases 43 (5), 564–568.

Perry, B. D., Grace, D., Sones, K., 2011. Livestock and global change special feature: Current drivers and future directions of global livestock disease dynamics. Proceedings of the National Academy of Sciences of the United States of America.

PREDICT Consortium, 2010. PREDICT Executive Summary.
URL `http://www.vetmed.ucdavis.edu/ohi/local-assets/pdfs/PREDICTexecsum.pdf`

Rabinowitz, P. M., Odofin, L., Dein, F. J., 2008. From "us vs. them" to "shared risk": can animals help link environmental factors to human health? EcoHealth 5 (2), 224–229.

Rabinowitz, R., Gordon, Z., Holmes, R., Taylor, B., Wilcox, M., Chudnov, D., Nadkarni, P., Dein, F., 2005. Animals as sentinels of human environmental health hazards: an evidence-based analysis. EcoHealth 2, 26–37.

Reyburn, H., Mbatia, R., Drakeley, C., Carneiro, I., Mwakasungula, E., Mwerinde, O., Saganda, K., Shao, J., Kitua, A., Olomi, R., Greenwood, B. M., Whitty, C. J. M., 2004. Overdiagnosis of malaria in patients with severe febrile illness in Tanzania: a prospective study. British Medical Journal 329 (7476), 1212.

Robertson, C., Sawford, K., Daniel, S. L. A., Nelson, T. A., Stephen, C., 2010. Mobile phone-based infectious disease surveillance system, Sri Lanka. Emerging Infectious Diseases 16 (10), 1524–1531.

Robertson, S. E., Suleiman, A. J., Mehta, F. R., al Dhahry, S. H., el Bualy, M. S., 1994. Poliomyelitis in Oman: acute flaccid paralysis surveillance leading to early detection and rapid response to a type 3 outbreak. Bulletin of the World Health Organization 72 (6), 907–914.

Rockx, B., van Asten, L., van den Wijngaard, C., Godeke, G.-J., Goehring, L., Vennema, H., van der Avoort, H., van Pelt, W., Koopmans, M., 2006. Syndromic surveillance in The Netherlands for the early detection of West Nile virus epidemics. Vector Borne and Zoonotic Diseases 6, 161–169.

Roth, F., Zinsstag, J., Orkhon, D., Chimed-Ochir, G., Hutton, G., Cosivi, O., Carrin, G., Otte, J., 2003. Human health benefits from livestock vaccination for brucellosis: case study. Bulletin of the World Health Organization 81 (12), 867–876.

Rouquet, P., Froment, J.-M., Bermejo, M., Yaba, P., Dlicat, A., Rollin, P. E., Leroy, E. M., 2005. Wild animal mortality monitoring and human Ebola outbreaks, Gabon and Republic of Congo, 2001-2003. Emerging Infectious Diseases 11 (2), 283–290.

Rowe, A. K., de Savigny, D., Lanata, C. F., Victora, C. G., 2005. How can we achieve and maintain high-quality performance of health workers in low-resource settings? Lancet 366 (9490), 1026–1035.

Rumisha, S. F., Mboera, L. E. G., Senkoro, K. P., Gueye, D., Mmbuji, P. K., 2007. Monitoring and evaluation of integrated disease surveillance and response in selected districts in Tanzania. Tanzania Health Research Bulletin 9 (1), 1–11.

Salman, M., 2003. Animal disease surveillance and survey systems: methods and applications. Iowa State Press, Ch. Surveillance and monitoring systems for animal health programs and disease surveys, pp. 3–13.

Scotch, M., Mattocks, K., Rabinowitz, P., Brandt, C., Feb 2010. A qualitative study of state-level zoonotic disease surveillance in new england. Zoonoses and Public Health.

Scotch, M., Odofin, L., Rabinowitz, P., 2009. Linkages between animal and human health sentinel data. BMC Veterinary Research 5, 15.

Shears, P., 2000. Communicable disease surveillance with limited resources: the scope to link human and veterinary programmes. Acta Tropica 76 (1), 3–7.

Shephard, R., 2006. The development of a syndromic surveillance system for the extensive beef cattle producing regions of Australia. Ph.D. thesis, University of Sydney.

Soares, M., Dumville, J. C., Oct 2008a. Critical appraisal of cost-effectiveness and cost-utility studies in health care. Evidence Based Nursing 11 (4), 99–102.

Soares, M., Dumville, J. C., 2008b. Economic evaluation of healthcare technologies using primary research. Evidence Based Nursing 11 (3), 67–71.

Somda, Z. C., Meltzer, M. I., Perry, H. N., Messonnier, N. E., Abdulmumini, U., Mebrahtu, G., Sacko, M., Tour, K., Ki, S. O., Okorosobo, T., Alemu, W., Sow, I., 2009. Cost analysis of an integrated disease surveillance and response system: case of Burkina Faso, Eritrea, and Mali. Cost Effectiveness and Resource Allocation 7, 1.

Soto, G., Araujo-Castillo, R., Neyra, J., Fernandez, M., Leturia, C., M. C., Blazes, D., 2008. Challenges in the implementation of an electronic surveillance system in a resource-limited setting: Alerta, in Peru. BMC Proceedings 2 (Suppl 3), S4.

Streefland, P. H., Chowdhury, A. M., Ramos-Jimenez, P., 1999. Quality of vaccination services and social demand for vaccinations in africa and asia. Bulletin of the World Health Organization 77 (9), 722–730.

The World Bank, 2010. People, Pathogens and Our Planet. Volume 1: Towards a One Health Approach for Controlling Zoonotic Diseases. The World Bank.
URL `http://siteresources.worldbank.org/INTARD/Resources/PPP_Web.pdf`

Thiry, E., Zicola, A., Addie, D., Egberink, H., Hartmann, K., Lutz, H., Poulet, H., Horzinek, M. C., 2007. Highly pathogenic avian influenza H5N1 virus in cats and other carnivores. Veterinary Microbiology 122 (1-2), 25–31.

USAID, 2009. UC Davis-Led Team Selected to Implement USAID Wildlife Surveillance Project to Detect and PREDICT Emerging Infectious Diseases. United States Agency for International Development (USAID).
URL `http://www.usaid.gov/press/releases/2009/pr091103.html`

Vetwork UK, 2011. Participatory Epidemiology.
URL `http://www.participatoryepidemiology.info/`

Vital Wave Consulting, 2009. mHealth for Development: The Opportunity of Mobile Technology for Heathcare in the Developing World. UN Foundation-Vodafone Foundation Partnership., washington, D.C. and Berkshire, UK.

Vourc'h, G., Bridges, V. E., Gibbens, J., Groot, B. D. D., McIntyre, L., Poland, R., Barnouin, J., 2006. Detecting emerging diseases in farm animals through clinical observations. Emerging Infectious Diseases 12 (2), 204–210.

Vrbova, L., Stephen, C., Kasman, N., Boehnke, R., Doyle-Waters, M., Chablitt-Clark, A., Gibson, B., Brauer, M., Patrick, D., 2009. Systematic Review of Surveillance Systems for Emerging Zoonoses.

Vrbova, L., Stephen, C., Kasman, N., Boehnke, R., Doyle-Waters, M., Chablitt-Clark, A., Gibson, B., FitzGerald, M., Patrick, D. M., Jun 2010. Systematic review of surveillance systems for emerging zoonoses. Transbound Emerg Dis 57 (3), 154–161.

Ward, M. R., Stallknecht, D. E., Willis, J., Conroy, M. J., Davidson, W. R., 2006. Wild bird mortality and West Nile virus surveillance: biases associated with detection, reporting, and carcass persistence. Journal of Wildlife Diseases 42 (1), 92–106.

Watkins, R. E., Eagleson, S., Hall, R. G., Dailey, L., Plant, A. J., 2006. Approaches to the evaluation of outbreak detection methods. BMC Public Health 6, 263.

WHO, 1997. Protocol for the evaluation of epidemiological surveillance systems. World Health Organization (WHO).
URL `http://whqlibdoc.who.int/hq/1997/WHO_EMC_DIS_97.2.pdf`

WHO, 2003. Guide to producing national health accounts with special applications to low-income and middle-income countries. World Health Organization (WHO).
URL `.http://www.who.int/nha/docs/English_PG.pdf`

WHO, 2005. Evaluating the costs and benefits of national surveillance and response systems. Methodologies and options. World Health Organization (WHO), WHO/CDS/EPR/LYO/2005.25.
URL `http://www.who.int/csr/resources/publications/surveillance/WHO_CDS_EPR_LYO_2005_25/en/index.html`

WHO, CDC, 2010. Technical guidelines for Integrated Disease Surveillance and Response in the African Region. World Health Organization (WHO) and National Center for Immunization and Respiratory Diseases Centers for Disease Control and Prevention Department of Health and Human Services.
URL `http://www.afro.who.int/en/clusters-a-programmes/dpc/integrated-disease-surveillance.html`

WHO, DFID, 2006. The control of neglected zoonotic diseases - a route to poverty alleviation. Report of a joint WHO/DFID-Animal Health Programme meeting with the participation of FAO and OIE, Geneva 20 and 21 Sept 2005. World Health Organization (WHO) and Department for International Development (DFID).
URL `http://www.who.int/zoonoses/Report_Sept06.pdf`

Wilson, N., Howden-Chapman, P., Baker, M. G., 2010. Co-benefits and 'no regrets' benefits of influenza pandemic planning. Influenza and Other Respiratory Viruses 4 (3), 113–115.

Woolhouse, M. E. J., 2002. Population biology of emerging and re-emerging pathogens. Trends in Microbiology 10 (10), S3–S7.

Woolhouse, M. E. J., Gowtage-Sequeria, S., 2005. Host range and emerging and reemerging pathogens. Emerging Infectious Diseases 11 (12), 1842–1847.

Yale Occupational and Environmental Medicine Program, 2010. The Canary Database.
URL `http://canarydatabase.org/`

Yang, C., Yang, J., Luo, X., Gong, P., 2009. Use of mobile phones in an emergency reporting system for infectious disease surveillance after the Sichuan earthquake in China. Bulletin of the World Health Organization 87 (8), 619–623.

Yu, P., de Courten, M., Pan, E., Galea, G., Pryor, J., 2009. The development and evaluation of a PDA-based method for public health surveillance data collection in developing countries. International Journal of Medical Informatics 78 (8), 532–542.

Zinsstag, J., Schelling, E., Roth, F., Bonfoh, B., de Savigny, D., Tanner, M., 2007. Human benefits of animal interventions for zoonosis control. Emerging Infectious Diseases 13, 527–531.