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Animal health surveillance for early detection of emerging infectious disease risks

by

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Abstract

The global public health community is facing the challenge of emerging infectious diseases. Historically, the majority of events have originated in the animal population. This research investigates animal health surveillance for early detection of emerging infectious disease risks. A mobile phoned-based surveillance system was designed and implemented in Sri Lanka to collect data from field veterinarians on their encounters with cattle, poultry, and buffalo. The system was both feasible and acceptable to users and stakeholders and provided timely animal health information in Sri Lanka. A review of literature from the fields of epidemic intelligence, surveillance, and military intelligence informed development of an emerging infectious disease intelligence framework applicable to surveillance initiatives that aim to use animals as sentinels for emerging infectious disease risks in low-resource settings. Application of this framework to the surveillance system piloted in Sri Lanka and ongoing diagnostic laboratory-based animal disease surveillance illuminated strengths and deficits in both surveillance efforts and demonstrated that mobile phone-based surveillance combined with ongoing diagnostic laboratory-based surveillance initiatives has the potential to contribute to emerging infectious disease intelligence in Sri Lanka. A focused ethnographic study was conducted with field veterinarians that participated in the surveillance system in Sri Lanka. Results found biases introduced into diagnostic laboratory data by field veterinarians in Sri Lanka who in part determine which clinical cases in animals reach the level of the diagnostic laboratory. This study also explored the factors that motivate and encourage these veterinarians to participate in pre-diagnostic surveillance initiatives. A focused ethnographic study was conducted also with private cattle veterinarians in Alberta that

participated in the Alberta Veterinary Surveillance Network, a pre-diagnostic surveillance system administered by the Government of Alberta. It demonstrated biases in diagnostic laboratory data that are introduced by the decision-making process these veterinarians go through as they determine the clinical cases that will reach the level of the diagnostic laboratory. It also explored the factors that motivate and encourage these veterinarians to participate in surveillance initiatives in Alberta. These two qualitative studies will inform surveillance efforts in the animal population that are dependent on veterinary involvement for data collection.

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List of Symbols, Abbreviations and Nomenclature

Symbol	Definition
ARD	Alberta Department of Agriculture and Rural Development
AVSN	Alberta Veterinary Surveillance Network
AVSN-VPS	Alberta Veterinary Surveillance Network-Veterinary Practice Surveillance
β	Effective contact rate
BSE	Bovine Spongiform Encephalopathy
c	Contact rate
CAHSN	Canadian Animal Health Surveillance Network
CDC	Centers for Disease Control and Prevention
CFIA	Canadian Food Inspection Agency
CMT	California Mastitis Test
CUSUM	Cumulative Sum
d	Duration of infectious period
DAPH	Department of Animal Production and Health
DS	Divisional Secretariat
E	Exposed
EID	Emerging Infectious Disease
ELISA	Enzyme-Linked Immunosorbent Assay
FMD	Foot and Mouth Disease
FVS	Field Veterinary Surgeon
GPS	Global Positioning Systems
h	Alarm threshold
HPAI	Highly Pathogenic Avian Influenza
I	Infectious
IDSAS	Infectious Disease Surveillance and Analysis System
k	Reference value
MD	Municipal District (Alberta)
OIE	World Organisation for Animal Health
p	Probability of transmission
PCR	Polymerase Chain Reaction
PDS	Prairie Diagnostic Services
R	Recovered
R_0	The basic reproductive ratio
RBPT	Rose Bengal Plate Test
S	Susceptible
SARS	Severe Acute Respiratory Syndrome
t	Time
T_g	Average transmission time
VIC	Veterinary Investigation Centre
VIO	Veterinary Investigation Officer
VRI	Veterinary Research Institute
WNv	West Nile virus

Epigraph

There are known knowns; there are things we know we know. We also know there are known unknowns; that is to say we know there are some things we do not know. But there are also unknown unknowns – the ones we don't know we don't know.

-Former United States Secretary of Defense Donald Rumsfeld

CHAPTER 1: INTRODUCTION

This thesis is based on five core ideas: 1) experience to date has shown that society has limited capacity to forecast emerging infectious diseases (EID) in time to mitigate their social and environmental impacts (Woolhouse, 2011); 2) early actions require early warning and there is a body of literature that suggests tracking reports from frontline health workers may allow for earlier EID detection and response (Buckeridge et al., 2002; Kohane, 2002; Lober et al., 2002); 3) the majority of recent EIDs have been zoonotic, suggesting that true early detection of EIDs will require tracking patterns of animal disease and pathogens (Taylor, Latham, & Woolhouse, 2001; Woolhouse & Gowtage-Sequeria, 2005); 4) many of the areas at highest risk for future EIDs are in tropical, low-resource countries, necessitating the development of early warning systems that are affordable and feasible within resource-limited settings (Jones et al., 2008; Keusch, Pappaioanou, Gonzalez, Scott, & Tsai, 2009); and 5) effective and reliable surveillance requires motivated participants (Singer et al., 2007; Wong, 2010; Wong, 2011) but there has yet to be research done on the human dimensions of participation in animal disease surveillance. Each of these ideas will be discussed in depth below.

This thesis describes the results from research in Sri Lanka and Canada that addresses key knowledge gaps associated with the five core ideas. Its goal is to provide practical insights for animal and public health practitioners intending to develop frontline animal health surveillance systems for early detection of EIDs that pose a threat to human health. The overarching question that guides this thesis is the following: Can frontline reporting of animal health-related events enhance capacity for early warning of EID events of significance to human health?

Conceptual foundation for the thesis

In recent years, the global public health community has faced the challenge of EID events (Wagner et al., 2006; World Health Organization [WHO], 2006b). Countries and communities have failed to predict specific EID events and in many cases have been ill-equipped to respond once a disease has emerged, making it difficult to contain both the disease and the social and environmental impacts of the disease (Wagner et al., 2006). A recent review that considers the challenge of prediction of EID events notes that while numerous studies have linked emergence or re-emergence of specific pathogens with particular drivers, most studies are descriptive in nature and the linking of pathogen emergence to drivers is based on a retrospective and subjective interpretation of events (Woolhouse, 2011). Woolhouse (2011) concluded that “the emergence of a specific pathogen may always be essentially unpredictable”. This author calls for more detailed characterization of the drivers behind EID events and investigations that detail the mechanisms of infectious disease emergence to help predict where and when EIDs are likely to happen, and whether they are likely to be a substantial threat to human or animal health. In the absence of the ability to predict EID events, it has been postulated that acquisition of information from frontline health care workers would move us much closer to the index case and thus increase our ability to rapidly detect and contain EIDs (Buckeridge et al., 2002; Kohane, 2002; Woolhouse, 2011). This approach has been developed mostly in human health, to a large extent in response to concerns for bioterrorism (Buckeridge et al., 2002; Hutwagner, Thompson, Seeman, & Treadwell, 2003; Kohane, 2002; Lober et al., 2002).

As a majority of EIDs are zoonotic (Christou, 2011; Taylor et al., 2001; Woolhouse & Gowtage-Sequeria, 2005), it has been further postulated that early detection of EID events in animals would allow the risk they pose to public health to be contained before spill over into the human population (WHO, 2006b). There has been little attention paid to how best to structure a system that uses animals as EID sentinels; a recent review found no evidence basis for EID surveillance system design (Vrbova et al., 2010). As most EIDs have arisen at lower latitudes (Jones et al., 2008) where many nations experience marked resource constraints, there needs to be consideration of how risk forecasting via animal health and disease data can be achieved in lower-resource settings. This issue has not been explored in the literature. Frontline animal disease surveillance will require motivated and engaged frontline animal health care workers (Chauvin & Valleron, 1998; de Stampa, Vedel, Bergman, Novella, & Lapointe, 2009; Hummers-Pradier et al., 2008). No research has been done on the human dimensions of animal disease surveillance.

Priority setting for emerging infectious disease surveillance

Infectious disease emergence from animals

New diseases in animals and people are being identified more frequently than ever before and this trend is expected to continue (Greger, 2007). Infectious diseases are deemed ‘emerging’ if they have only recently arisen or if they are previously known diseases that are increasing in host or geographic range or incidence (S. Morse, 2004). It has been estimated that between 60 and 75 percent of EIDs in people have arisen from animals (Keusch et al., 2009; Taylor et al., 2001; Woolhouse & Gowtage-Sequeria, 2005). Strategies for limiting the impact of zoonotic EIDs can be broadly categorized as intervention at one or more of three levels: (i) controlling infections in people; (ii) blocking transmission of pathogens from animals to people; and/or (iii) preventing or controlling disease in animals (Haydon, Cleaveland, Taylor, & Laurenson, 2002). Despite significant effort and funds targeting the first strategy, the global public health community continues to be caught off guard by EIDs (Daszak, 2009). For example, the emergence of Nipah virus from bats and swine in Malaysia led to 265 human cases of acute encephalitis and 105 deaths, significant economic losses, and near collapse of the local swine industry (Chua, 2003). Severe acute respiratory syndrome (SARS), which emerged from civet cats in the Guangdong province of China, led to 331 reported probable cases in southeast Asia, 44 deaths in Singapore, Vietnam, Thailand, Malaysia, and Indonesia, and is estimated to have cost east and southeast Asia 18 billion USD (Coker, Hunter, Rudge, Liverani, & Hanvoravongchai, 2011). The effects of EIDs are experienced globally: the same outbreak of SARS is estimated to have cost the Canadian economy 1.5 billion CAD in 2003 (Darby, 2003) and resulted in 251 human cases and 43 deaths (Oehler, 2010). It is now strongly believed that the third strategy, prevention or control of disease in animals, is optimal for limiting the impact of zoonotic EIDs (Keusch et al., 2009; WHO, 2006b).

The risk of future emerging infectious disease events in low-resource, lower latitude contexts

Recently there has been effort to review past EID events in order to understand drivers of infectious disease emergence (Jones et al., 2008; Keesing et al., 2010; Smolinski, Hamburg, & Lederberg, 2003; Woolhouse & Gowtage-Sequeria, 2005). Increasing demand for animal protein, expansion of intensive animal agricultural systems, long-distance transportation of live animals, consumption of wild animals, and habitat destruction have been implicated as important factors underlying infectious disease emergence (Greger, 2007; Woolhouse & Gowtage-Sequeria, 2005). These largely anthropogenic factors are expected to become increasingly important as the global human population grows (Smolinski et al., 2003). Jones et al. (2008) generated risk maps based on socio-economic, environmental and ecological variables that correlate with past EID events. Their analysis suggests that EID hotspots from zoonotic pathogens are more concentrated in lower-latitude, low-resource countries. As a result of these findings the need for surveillance methods that are feasible and effective in low-resource, lower latitude contexts has been emphasized (Daszak, 2009; Keusch et al., 2009). For the purpose of this thesis, a low-resource setting, country, or context is defined as one in which inadequate scientific capacity and infrastructure slow the development and uptake of health-related practices (Singer et al., 2007).

The global public health community recognizes that strategies and responses to EIDs, including surveillance initiatives, need to be tailored to the circumstances and needs of a particular country (Food and Agriculture Organization of the United Nations [FAO], 2009; WHO, 2006a). Therefore, strategies to protect the global community from EIDs arising from lower latitudes must take into account the financial, infrastructural and political realities of those countries in order to develop reliable and sustainable programs for EID early detection and control. Simply applying public health and animal health programs designed to function in high-resource countries to low-resource countries is unlikely to be an effective strategy. Y. Lin and C. Heffernan (2009), for example, documented the challenges of applying information technology in low-resource settings and the need to accommodate local farmer needs and abilities.

Theoretical support for emerging infectious disease early detection as a component of control strategies

Conceptual models and parameters such as the basic reproductive ratio of infections and disease generation time provide a theoretical foundation for early disease detection as an essential component of EID control strategies (see below). The basic reproductive ratio of infections (R_0) has allowed researchers to investigate a variety of control measures including vaccination, serological testing, clinical examination, treatment interventions, and culling at the herd and population levels (Keeling, Woolhouse, R. May, Davies, & Grenfell, 2003; O'Reilly, Medley, & L. E. Green, 2010; Tildesley et al., 2010; Woolhouse, Haydon, & Bundy, 1997). Conceptual models have been used to investigate the potential success of public health interventions and combined with real-world data to gain insights into the epidemiology of disease and estimate parameters, including R_0 (L.E. Green & Medley, 2002). Some of these models have demonstrated how public health measures that allow for containment of the first cases in outbreaks, including isolating symptomatic individuals and tracing and quarantining those individuals that were in contact with symptomatic individuals, can permit control of EID outbreaks (C. Fraser, Riley, R. Anderson, & Ferguson, 2004).

R_0 can be used to illuminate the importance of EID early detection and further understanding of the risk posed by EIDs. It is a theoretical concept that is defined as the number of individuals secondarily infected by a single infectious individual over the course of that individual's infectious period in an entirely susceptible population (J. Heffernan, Smith, & Wahl, 2005). Whereas the criterion of an entirely susceptible population may not be valid for endemic infections, it may be closer to the reality in the case of EIDs. When R_0 is less than one, the infection will eventually be cleared from the population as each infected individual gives rise to, on average, less than one new infected individual (J. Heffernan et al., 2005). When R_0 is greater than one the pathogen is capable of establishing itself in the susceptible population (J. Heffernan et al., 2005).

There are numerous uses of the R_0 concept, including gauging the risk of an epidemic or pandemic from particular EIDs, evaluating disease control measures, and quantifying the efficacy of vaccination on the spread of infection (Nokes & R. Anderson, 1988; Tildesley et al., 2006; Woolhouse et al., 1997). R_0 is the product of the effective contact rate and the duration of the infectious period (*cpd*) (Dohoo, Martin, & Stryhn, 2010). An individual makes contact with other individuals in a population at the rate *c* in a time period. The probability of transmission of infection between one individual that is infectious and one that is susceptible is denoted *p*. The product of the contact rate and the probability of transmission (*cp*) is referred to as the effective contact rate and is denoted ß. Finally, the duration of the infectious period is denoted *d*. Infectious disease control measures are targeted at reducing ß. Broadly speaking, outbreak control measures reduce ß, which leads to a reduction in R_0 (Chowell et al., 2004; C. Fraser et al., 2004; O'Reilly et al., 2010). If control measures are sufficient and effective given the transmission characteristics of a particular infectious disease, R_0 can be driven to less than 1 and the outbreak brought under control.

Another important concept for supporting an early detection approach for EID management is disease generation time (T_g) (C. Fraser et al., 2004), sometimes referred to as average transmission interval (P. Fine, 2003). T_g is defined as the mean time interval between infection of one individual and subsequent infections arising from that individual (P. Fine, 2003; C. Fraser et al., 2004). Together R_0 and T_g set the time scale for growth of an epidemic and dictate the speed with which control measures must be instituted to avert large-scale outbreaks (C. Fraser et al., 2004). They provide the theoretical foundation for the argument that early detection is paramount to EID preparedness that serves to limit the adverse outcomes of pandemics: the earlier a case of an EID is detected and control measures are put in place to prevent secondary infections, the fewer the number of secondary infections (assuming that the control measures are effective and reduce the number of subsequent infections), which may serve to reduce R_0 and therefore the extent of EID spread. For example, these concepts have been used in the literature to demonstrate how the SARS epidemic was eventually brought under control in part because of a reduction in delay between onset of symptoms and case isolation (C. Fraser et al., 2004).

At a population level, early detection of infectious disease outbreaks limits the number of disease generation time periods that have occurred since the index case and, therefore, the number of infected individuals in the population before public health measures are implemented to control disease spread (Donnelly et al., 2003). In the case of zoonotic EIDs, it can be surmised that the smaller the number of infectious animal cases at the time of commencing disease control, the smaller the number of transmission opportunities and the lower the number of secondary human cases. A recent review demonstrated that an increase in the number of primary infectious disease cases introduced into a human population by a zoonotic disease reservoir leads to an increased outbreak size in people (Woolhouse & Gowtage-Sequeria, 2005). For outbreaks of zoonotic EIDs in animals, reducing animal epidemic size should contribute to a reduction in the number of human cases. Therefore, the arguments for early detection of zoonotic EIDs in animals as part of public health protection are theoretically valid.

Regardless of whether the target is animal or human populations, calculating R_0 and making predictions about the likely outcome of different intervention strategies during outbreaks requires accurate parameterization (Feng, Xu, & Zhao, 2007; Wearing, Rohani, & Keeling, 2005). Accurate parameterization is dependent on two factors: model formulation that is based on epidemiological realistic assumptions; and high-quality data from the initial stages of the outbreak that are used to estimate model parameters (Feng et al., 2007; Wearing et al., 2005). Therefore, in order to exploit mathematical models in the management and control of EID events, timely and accurate surveillance data and information on EID events in animals are essential for protection of public health.

Animals as sentinels for human health risks

A sentinel health event can be defined as a ‘preventable disease, disability, or untimely death whose occurrence serves as a warning signal that the quality of preventive and/or therapeutic care may need to be improved’ (Rutstein et al., 1983). This concept has been extended to animal health: ‘sentinel colonies’ or ‘sentinel herds’ are monitored to determine if communicable diseases or toxicants could be affecting the larger animal population (Rabinowitz, Scotch, & Conti, 2009). Further, humans have long recognized the value of animals as sentinels for human health risks (Rabinowitz et al., 2009; Stephen & Ribble, 2001). The classic historical example comes from mining in the early 1900s when workers would take canaries into the mines with them to provide warning of the presence of carbon monoxide (Rabinowitz et al., 2009; Stephen & Ribble, 2001). These birds were the ideal sentinels: they were sensitive to the hazard, experienced recognizable effects due to exposure to the hazard, displayed signs of exposure before people, and shared the same exposure as the people of interest (Rabinowitz et al., 2009; Stephen & Ribble, 2001). Sick animals have signalled other environmental toxic health risks to humans, including asbestos, mercury, and lead exposure (Halliday et al., 2007; Rabinowitz et al., 2008; Stephen & Ribble, 2001).

Animal populations experience adverse health consequences from infectious diseases that also impact humans and therefore could serve as important sentinels of infectious disease risks that affect humans (Figure 1.1) (Rabinowitz et al., 2008). The ideal animal sentinel would: be exposed to the same infectious disease hazard at the same level, or at a higher level, compared to humans; be more susceptible to a particular infectious disease hazard compared to humans; and display overt, easily recognizable clinical signs of disease (Committee on Animals as Monitors of Environmental Hazards, 1991; Rabinowitz et al., 2009; Rabinowitz et al., 2008). Additionally, the incubation period would be short and would be shorter than the latency period so the hazard could potentially be contained to the animal population (Rabinowitz et al., 2009; Rabinowitz et al., 2008; van der Schalie et al., 1999).

Field experience with animals as sentinels for emerging infectious disease early warning

Retrospective analysis has demonstrated the potential value of animal sentinels in early identification of infectious disease hazards: dying crows preceded the West Nile virus (WNv) outbreak in humans in New York City (Rabinowitz et al., 2009); pronounced neurological and respiratory syndrome in pigs in peninsular Malaysia was the first indication of the emergence of Nipah virus that infects both swine and people (Mohd Nor, Gan, & Ong, 2000); and deaths from Ebola virus amongst primate sentinels have preceded Ebola virus outbreaks in humans (Rouquet et al., 2005). Each of these examples is discussed below in detail.

In the case of WNv in New York City, the outbreak in humans was announced in early September 1999 after a clinician noticed and reported a cluster of unusual cases of neurological disease (A. Fine & Layton, 2001). However, veterinarians and the wildlife community had been aware of a large avian die-off since early- to mid-August 1999 (A. Fine & Layton, 2001). The announcement of the human outbreak prompted a veterinary-led investigation into the cause of the avian deaths (A. Fine & Layton, 2001). Through this effort WNv was identified in several dead crows and zoo birds, and subsequently in humans (A. Fine & Layton, 2001). Since the emergence of WNv, significant effort has been made to improve communication between the animal and human health sectors and integrate disease surveillance programs (Keusch et al., 2009). Additionally, monitoring of bird populations has been used to forecast a change in risk to human communities as the WNv epidemic has expanded (Eidson et al., 2001).

The spill over of Nipah virus from fruit bats to pigs in peninsular Malaysia is believed to have happened early in 1997 (Chua, Chua, & Wang, 2002). The outbreak of neurological and respiratory syndrome in swine began sometime in 1997 (Uppal, 2000). Initially the outbreak was not of significant concern because pig morbidity and mortality rates were not excessive and the clinical presentation fit with classical swine fever, a non-zoonotic disease found in Malaysia (Chua, 2010; Mohd Nor et al., 2000). In September 1998, health authorities began reporting suspected cases of Japanese encephalitis in humans (Uppal, 2000). However, during February 1999, when control measures proved less effective than expected, epidemiologic characteristics were found to be inconsistent with an outbreak of Japanese encephalitis, and an association between the disease outbreak in swine and the human outbreak was noted, virus isolation studies in humans began (Wagner et al., 2006). A new EID was confirmed when Nipah virus was isolated from a human patient in early 1999 (Wagner et al., 2006). By the time a common etiology for the two outbreaks was noted the disease had spread to a second region in Malaysia and Singapore and there had been over 300 human cases and in excess of 100 deaths (Chua et al., 2000). Further study indicated that the disease spread around Malaysia and into Singapore through the movement of swine (Chua, 2010) and that the vast majority of human cases were the result of close contact between infected swine and people (Chua, 2010; Wagner et al., 2006). Retrospective analysis also revealed that the index human cases were recorded between June and September of 1997 (Uppal, 2000).

Finally, outbreaks of Ebola virus in people and nonhuman primates cause severe hemorrhagic fever and high case-fatality rates. Many of the recent outbreaks in people have resulted from handling infected wild animal carcasses (Leroy et al., 2004). After the first outbreak of Ebola virus during 2001 between Gabon and the Republic of Congo, the Animal Mortality Monitoring Network was created with the aim to predict and prevent human Ebola outbreaks (Rouquet et al., 2005). Ebola virus outbreaks began in wild animal populations before each of the five Ebola virus outbreaks in people and on two occasions the human health authorities in Gabon and the Republic of Congo were informed of a heightened risk of Ebola virus outbreaks in people based on detection of Ebola virus in wild animals found dead (Rouquet et al., 2005). However, adoption of preventative measures by the human population was lacking and public health responses failed to prevent Ebola virus outbreaks in humans weeks after the index cases in animals (Rouquet et al., 2005).

Linking animal sentinels with the need for surveillance

One means of gaining an understanding of animal sentinels and animal health-related events that represent potential human health risks is through surveillance. Public health surveillance is defined as ‘the ongoing, systematic collection, analysis, interpretation, and dissemination of data regarding a health-related event for use in public health action to reduce morbidity and mortality and to improve health’ (German et al., 2001). Data from public health surveillance systems serve a variety of functions including measuring disease burden. This role is further subdivided into identification of changes to health-related factors, populations at high risk for health-related events, and EID events, which inform epidemiologic research (German et al., 2001). Data from surveillance for EID events can include: cases of specific diseases in animals or people; sentinel events that could indicate an EID outbreak in animals or people; and outbreak and demographic characteristics associated with health-related events (German et al., 2001; Wagner et al., 2006). Data from EID outbreaks are used to inform conceptual models, which provide insight into infectious disease dynamics and predict the impact of preventive measures (Keusch et al., 2009). The decisions and actions that result from surveillance activities are dependent upon the analysis of timely, reliable, and meaningful data to inform them (Figure 1.2) (German et al., 2001; Wagner et al., 2006).

The public health community has failed to fully realize the opportunity to utilize animal sentinels for surveillance of human health risks to enable a response *before* there is morbidity and mortality in humans: the cases detailed previously illustrate that while animals can serve as sentinels of infectious disease risks to humans, warning signals have only been recognized or deemed significant in retrospect. Often investigation of human disease outbreaks leads to in-depth investigation of animal health-related events as opposed to the converse, and even when infectious disease risks in animals have been pre-emptively recognized and brought to the attention of the public health community, the response has been insufficient to prevent outbreaks of human disease (Rabinowitz et al., 2009; Rouquet et al., 2005). There are multiple reasons behind these failures: while outbreaks and die-offs in animal populations occur relatively commonly (Carey, 2000; D.E. Green, Converse, & Schrader, 2002; Gulland & Hall, 2007), the occasions in which they have indicated an EID risk to humans have been relatively few (Wagner et al., 2006); and there is an absence of information concerning disease expression across species, species differences in host-pathogen relationship, and differences in animal and human exposure to risks and pathogen susceptibility (Rabinowitz et al., 2008). However, the strong theoretical support for the use of animals as sentinels for EID risks to humans and the importance of EID early detection, the lessons learned from past experience with EIDs that can be used to make recommendations to guide future research and policy development, and the risk posed by EIDs originating in animal populations taken together serve as ongoing motivation for action. The call from the global health community to address some of the knowledge gaps (Keusch et al., 2009; Woolhouse, 2011) and improve surveillance efforts to enhance our ability to use animals as sentinels for EID risks to humans (Daszak, 2009; Keusch et al., 2009) is becoming increasingly urgent. It has included a call for integration of multiple data sources, including observations from frontline health care workers, and research into the human dimensions of disease emergence and spread, risk perception and behaviours, and disease surveillance (Keusch et al., 2009).

Enhancing early detection of emerging infectious disease events through frontline or pre-diagnostic surveillance

Time lags and biases in diagnostic laboratory-based surveillance in the animal health field

Traditional methods of infectious disease surveillance in animal and human health have revolved around laboratories to which samples from clinical cases are submitted for diagnostics in hopes that an etiologic diagnosis can be made (Tataryn et al., 2007; Wagner et al., 2006). The contribution of diagnostic laboratory-based surveillance to early detection of outbreaks and EIDs is compromised by the time lag between the onset of clinical signs and when an etiologic diagnosis is made and the availability of diagnostic laboratory tests to identify the infectious disease agent (Doherr & Audige, 2001). In addition, submission biases restrict the type and number of potentially infectious cases that are submitted to a diagnostic laboratory (Gibbens et al., 2008; Zurbrigg, 2009). This issue is particularly relevant in the animal health field where, in the majority of cases, producers or animal owners bear the cost of diagnostic laboratory testing. Therefore, diagnostic laboratory-based surveillance may not provide the timely detection needed to gain the advantages of early detection of EIDs (Eidson et al., 2001).

Human decision making and diagnoses at the level of the laboratory as an obstacle to emerging infectious disease early detection

In order for an etiologic diagnosis to be made at the level of the diagnostic laboratory when a clinical case occurs in an animal population, there is a series of human judgements that must take place: the animal(s) must show clinical signs of disease, which must be recognized by a producer, animal owner, or member of the public (in the case of a health-related event in wildlife). This person must be sufficiently concerned to report the case to a veterinarian or appropriate government authority, or be prepared to submit samples to a diagnostic laboratory independently. Appropriate samples must be collected and submitted, the diagnostician must decide on which tests to conduct, and the laboratory must be capable of isolating the etiologic agent or making a definitive diagnosis. In veterinary medicine, the producer or owner often reports the case to a veterinarian. The veterinarian must examine the animal, conclude that diagnostic laboratory testing is warranted, and gain agreement from the producer or owner to submit samples (Figure 1.3) (Doherr & Audige, 2001; Tataryn et al., 2007).

The time lags and biases attributed to clinician and animal owner decisions to submit samples to diagnostic laboratories mean that diagnostic laboratory-based surveillance alone is inadequate for early identification and response to EID events (Centers for Disease Control and Prevention [CDC], 2000; Teich, Wagner, Mackenzie, & Schafer, 2002; Wagner et al., 2006).

Experience with frontline or pre-diagnostic surveillance methodologies in human health

Increasing global concern around the threat of bioterrorism has helped to generate interest in the development of new surveillance methods in the human health field (Wagner et al., 2006). Syndromic surveillance is of particular interest. It is defined as the use of pre-diagnostic data to identify outbreaks earlier than would have been possible with confirmed diagnoses (Mandl et al., 2004). A number of studies have demonstrated that utilizing syndromic surveillance methods can enable more timely detection of infectious disease outbreaks compared to traditional surveillance methods alone (R. Heffernan et al., 2004; Josseran, Nicolau, Caillère, Astagneau, & Brücker, 2006; Lemay, 2008; Smith et al., 2006). As an example, visits to emergency departments for respiratory illness and fever among young children peaked 1 to 4 weeks before influenza virus was isolated within an Ottawa community (Lemay, 2008). Most examples that demonstrate the utility of syndromic surveillance methods for early detection of outbreaks come from the human health field and high-resource countries (Bravata et al., 2004). Many systems exploit electronic data that are being collected for other purposes and rely on internet connectivity for data transmission (Bravata et al., 2004; Chretien et al., 2008). In syndromic surveillance, focus is diverted away from definitive diagnoses and onto patterns in behaviour, symptoms, signs, or laboratory findings that can be tracked through a number of data sources (Figure 1.4). One useful data source in syndromic surveillance is encounters with frontline health care workers: in the case of an EID event, a behavioural change in people and the clinical signs and symptoms with which they present is reflected in the data generated through their interactions with frontline health care workers and the health care system (Mandl et al., 2004). Detection of potential EID outbreaks through syndromic surveillance can lead to public health investigations, adoption of outbreak control measures, and serve to augment and inform diagnostic laboratory-based surveillance programs (Lemay, 2008). Given the theoretical justification and experience with animal sentinels described above, it is plausible that syndromic surveillance methodologies that target the animal population might prove critical for timely detection of EID risks. The advent of syndromic surveillance does not detract from the need for robust diagnostic laboratory infrastructure as part of any EID surveillance strategy: often laboratory tests are necessary to confirm an etiologic diagnosis (Figure 1.4), determine if changes in patterns detected through syndromic surveillance represent an EID event, and guide EID control strategies (Gibbens et al., 2008; Rodier, Greenspan, Hughes, & Heymann, 2007; Torres-Slimming et al., 2006).

Challenges and solutions to utilization of pre-diagnostic surveillance methodologies in low-resource countries

Many early syndromic surveillance efforts were mounted in high-resource countries (Wagner et al., 2006, e.g., Bradley, Rolka, Walker, & Loonsk, 2005; R. Heffernan et al., 2004; Lewis et al., 2002; Lombardo, Burkom, & Pavlin, 2004). However, as the field has moved forward there has been interest in adapting systems for EID event detection in low-resource countries, in part in response to the risk posed by EIDs in these regions (Chretien et al., 2008; L. May, Chretien, & Pavlin, 2009). It is hypothesized that syndromic surveillance methods could play an even greater role in identification of EID outbreaks in low-resource countries because of the infrequent use of diagnostic laboratory confirmation in these settings and would permit automated detection of changes to trends in morbidity from syndromes associated with diseases of public health importance, which could lead to laboratory-based investigation and implementation of control measures (Chretien et al., 2008; L. May et al., 2009).

There are a number of obstacles to syndromic surveillance particular to low-resource settings including: limited existing electronic data sources that can be leveraged in pre-diagnostic surveillance programs; limited access to the internet; and limited existing human resources in epidemiology, data management and analysis, and use of computers (Chretien et al., 2008; L. May et al., 2009). Successful applications have demonstrated that all of these challenges can be overcome (Lombardo & Buckeridge, 2006; Soto et al., 2008). One strategy adopted by a number of surveillance systems in low-resource countries to overcome some of these obstacles is utilization of extensive and low-cost mobile phone networks for the purposes of data collection and dissemination (Aanensen, Huntley, Feil, al-Own, & Spratt, 2009; Randrianasolo et al., 2010; Soto et al., 2008; Yang, Yang, Luo, & Gong, 2009). Often participants have limited experience with epidemiology and surveillance and therefore there is a lack of reporting culture that exists in many of the contexts where these systems are being piloted (Soto et al., 2008). This challenge has been addressed primarily through extensive training on the surveillance system and in principles of epidemiology more broadly (Soto et al., 2008). Though mobile phone networks are extensive in low-resource contexts, access can be limited in very remote settings (Soto et al., 2008) and data networks have much more limited coverage (Aanensen et al., 2009). This challenge has been addressed primarily by developing systems that are dependent on mobile phone networks (Randrianasolo et al., 2010; Soto et al., 2008; Yang et al., 2009) and decoupling data collection and storage from the need for data network connectivity (Aanensen et al., 2009). Finally, the delays in reporting and high numbers of errors during implementation phases have had to be addressed through training, monitoring of data, supervision by local personnel (Randrianasolo et al., 2010; Soto et al., 2008), and utilization of technology that is ubiquitous within particular settings (Yang et al., 2009). In addition, when adequately designed and implemented, syndromic surveillance systems in low-resource countries have allowed for outbreak identification and characterization, indicating that syndromic surveillance efforts in low-resource contexts are not just theoretically feasible, but in reality can provide important understanding and response to infectious diseases in these regions (Lombardo & Buckeridge, 2006; Torres-Slimming et al., 2006).

Pre-diagnostic surveillance methodologies in animal health

The usefulness of syndromic surveillance in human health combined with the risk posed by EID events in animals and the limitations of diagnostic laboratory-based surveillance methods have generated interest among governmental organizations and members of the research community in adapting pre-diagnostic surveillance techniques for use in the animal population (Keusch et al., 2009; Surveillance Group on Diseases and Infections of Animals, 2003; WHO, 2006b). A number of potential data sources have been proposed and explored: veterinary case data (Vourc'h et al., 2006); specific clinical syndromes from veterinarians (Davies et al., 2007; De Groot, Spire, Sargeant, & D. C. Robertson, 2003; Vourc'h et al., 2006); atypical case presentations to veterinarians (Vourc'h et al., 2006); animal movement patterns (Fevre, Bronsvoort, Hamilton, & Cleaveland, 2006);

abattoir data (Thomas, 2010; Weber et al., 2011); diagnostic laboratory test requests (Dorea et al., 2011a; Shaffer et al., 2007); insurance data (Egenvall, Bonnett, Olson, & Hedhammar, 1998); auction market observations (Van Metre, Barkey, Salman, & Morley, 2009); animal health-related events in zoos (McNamara, 2007); herd management data (De Vries & Reneau, 2010); observations from producers and stock workers (Shephard, Toribio, Cameron, Thompson, & Baldock, 2006); voluntary notifications from veterinarians (Bartels et al., 2006); and animal mortality data (Rouquet et al., 2005).

A recent review of the literature by Dorea, Sanchez, and Revie (2011) detailed veterinary syndromic surveillance initiatives. The thirteen systems identified by the review operated within high-resource nations including New Zealand, France, United States, The Netherlands, Australia, United Kingdom, and Canada (Dorea et al., 2011b). Each system used one or a combination of the following data sources: specific clinical syndromes from veterinarians; atypical case presentations to veterinarians; diagnostic laboratory data; unsolved cases by farmers or veterinarians; observations from producers and stock workers; and auction market observations (Dorea et al., 2011b). Dorea et al.'s (2011b) review suggests that: (i) there is a lack of animal syndromic surveillance systems that have been developed for EID event detection specifically in low-to-middle countries despite of the risk posed by EIDs in these regions; and (ii) the majority of pre-diagnostic surveillance methods in the animal health field require the involvement of people, in particular veterinarians, who are in the position to generate the data sources listed previously.

A second recent review of the literature concerning emerging zoonoses surveillance systems found that none of the systems that used animal disease data have been evaluated using the CDC evaluation criteria (Vrbova et al., 2010). This deficiency could be in part because the CDC guidelines do not take into account the fact that using human health data to measure or monitor trends in the burden of human disease is very different from using animals as sentinels for EID health risks to humans. Surveillance systems require evaluation to demonstrate their usefulness, garner ongoing support from stakeholders, and document features that make them successful to inform upgrades and future efforts (German et al., 2001; Vrbova et al., 2010).

There is a need to enhance EID surveillance efforts in low-resource countries (Chretien et al., 2008), as well as a need for better approaches to pre-diagnostic EID surveillance system evaluation (Chretien, Tomich, Gaydos, & Kelley, 2009). One of the major gaps in knowledge that is critical to evaluation is the role of frontline animal health care workers as data providers in pre-diagnostic surveillance methodologies.

Understanding human dimensions of surveillance

The impact of human decisions on surveillance

The decision to report a suspected EID event at the local, regional, national levels is critical to the function of an EID surveillance system (Keusch et al., 2009). One of the lessons that can be learned from the health-related biotechnology field is that early engagement of a motivated and enabled group of people is critical to the long-term success of health-related initiatives (Singer et al., 2007). There is a need to understand the ability and willingness of veterinarians to participate in pre-diagnostic frontline surveillance initiatives and the factors that inspire initial and ongoing involvement in order for these systems to be most effective, in both low-resource contexts and high-resource contexts.

Current deficits in the literature

Qualitative research provides insight into human decisions and behaviour (Given, 2006). Qualitative approaches are not intended to permit researchers to make any statistical inferences from their findings that are generalized to the wider population. Instead, they allow researchers to gain a deeper understanding of the role that beliefs, circumstances, motivations, and context play in a variety of human behaviours, including decision making (Given, 2006). In other words, the strength of qualitative research is its ability to help answer *why* particular behaviours occur or to describe processes as opposed to outcomes (Given, 2006) and thus are well suited to providing insight into the human dimensions of surveillance. Qualitative research methods are being used increasingly in veterinary medicine to explore a range of topics, including treatment choices of farmers (M. Vaarst, Paarup-Laursen, House, Fossing, & Andersen, 2002; M. Vaarst et al., 2003), the human-animal bond (Lund, Eggertsson, Jorgensen, Grondahl, & Eggertsdottir, 2009), and perceptions of the monetary aspects of veterinary care (Coe, Adams, & Bonnett, 2007). As an example, qualitative methods have helped to illuminate that discussions between veterinarians and clients around the monetary costs of veterinary care should address the topic of the value of services and procedures from the perspective of animal health and well-being (Coe et al., 2007). They have also been used in low-resource settings to identify factors that impact the uptake and application of human health-related ideas, technologies, and practices (Arvelo et al., 2011; Singer et al., 2007; Weigel & Armijos, 2001; Wong, 2010; Wong, 2011). They have been used to explore the use of health data in public health practice, as well as factors that promote or inhibit use of these data (Bloom et al., 2000; Pope & Counahan, 2005; Wilkinson, Michie, & McCarthy, 2007). Though the human element of EID disease surveillance is critical, qualitative methods have not been used to study the role of veterinarians as decision makers in diagnostic laboratory sample submission or the potential role for veterinarians in pre-diagnostic frontline EID surveillance systems. A detailed study of veterinary decision-making is essential to inform designers and implementers of EID surveillance programs if the intended outcome is a sustainable and reliable system. Most importantly, these insights into beliefs, behaviours, and decisions need to be relevant to the local context where veterinarians are making decisions to ensure system relevance, uptake, and sustainability at a local level.

Thesis objectives and structure (Figure 1.5)

The key objectives of my research were:

1) To design and field test a mobile phone-based pre-diagnostic surveillance program, the Infectious Disease Surveillance and Analysis System (IDSAS), that allowed veterinarians in the field to report animal health information in the resource-limited setting of Sri Lanka.

My goal was to present a descriptive analysis of the IDSAS, data describing submission patterns from this pilot project, examples of the data collected, and a discussion of obstacles and opportunities encountered during design and implementation to determine if mobile phone technology could allow for collection of data that might permit detection of sentinel animal health events that could indicate an EID risk to humans.

2) To develop an EID intelligence framework informed by the published literature that better reflects the goals of using animals as sentinels for EID health risks to humans.

   My goal was to develop a means to inventory and describe attributes of animal health disease surveillance systems that would enable evaluators to determine if the system of interest plausibly provides the information necessary to forecast an EID risk to humans and motivate a public health response.

3) To apply the EID intelligence framework to the IDSAS to determine if the IDSAS has the potential to aid in EID early warning in Sri Lanka.

   My goal was to apply the framework to the IDSAS and the current diagnostic laboratory-based disease surveillance system in Sri Lanka to illuminate strengths and deficits in these surveillance programs for EID early warning and to inform future efforts to enhance EID early warning capacity in Sri Lanka.

4) To further understanding of the human dimension inherent to the decision-making process veterinarians go through when they approach clinical cases and determine whether diagnostic laboratory testing is warranted.

My goal was to use a qualitative approach to describe the sampling bias veterinarians in low-resource and high-resource settings, Sri Lanka and Alberta respectively, introduce into diagnostic laboratory-based surveillance.

5) To investigate the ability and willingness of veterinarians in Sri Lanka and Alberta to participate in pre-diagnostic infectious disease surveillance initiatives.

   My goal was to use a qualitative approach to describe the complex of factors that affect the ability and willingness of veterinarians in Sri Lanka and Alberta to participate in pre-diagnostic surveillance systems in order to inform ongoing and future efforts to engage veterinarians in these types of initiatives.

In chapter 2, I address my first objective by examining the IDSAS in Sri Lanka. Data for this chapter include: descriptions of the system and information structure; measures of data completeness and submission patterns; a description of the preliminary IDSAS data; a statistical surveillance example using the data generated by the IDSAS; and a description of the key lessons learned during system implementation. The purpose of this effort was to answer the question ‘can mobile phone technology be utilized in a lower-resource setting to generate information on an animal population that could serve as a sentinel for EID health risks to humans?’.

In chapter 3, I focus on objectives two and three and present an EID intelligence framework based on literature from the fields of surveillance, epidemic intelligence, and military intelligence. This framework was applied to the IDSAS and Sri Lanka’s animal diagnostic laboratory-based surveillance infrastructure to assess the potential of the

IDSAS to contribute to EID intelligence in Sri Lanka. Data for this chapter include: a scoping review of literature from the surveillance, epidemic intelligence, and military intelligence fields; the data set from the IDSAS; a detailed description of diagnostic laboratory-based disease surveillance in Sri Lanka; diagnostic laboratory data from Sri Lanka; Sri Lanka Census of Agriculture data; and a description of information flow within the government veterinary services in Sri Lanka. The purpose of this effort was to answer the question ‘do pre-diagnostic disease surveillance methodologies combined with ongoing diagnostic laboratory-based surveillance systems in low-resource settings provide information on animal health-related events that satisfies the attributes required for early warning of EID events?’.

In chapter 4, I examine objectives four and five through a focused ethnographic study of government field veterinarians from Sri Lanka who participated in the IDSAS. Data sources include transcripts of in-depth interviews with study participants, memos, a reflective journal, and fieldnotes collected during the research process. The purpose of this chapter was to help answer two questions: ‘how might diagnostic laboratory-based disease surveillance data from Sri Lanka be biased as it is government field veterinarians who in part determine which cases are submitted to diagnostic laboratories?’ and ‘how can we enable and motivate government field veterinarians in Sri Lanka to participate in pre-diagnostic surveillance initiatives?’.

In chapter 5, I attend also to objectives four and five though a focused ethnographic study with cattle veterinarians who participated in the Alberta Veterinary Surveillance

Network-Veterinary Practice Surveillance, a disease surveillance initiative that allows cattle veterinarians in Alberta to submit pre-diagnostic case data to a centralized system. Data sources include transcripts of in-depth interviews with study participants, memos, a reflective journal, and fieldnotes collected during the research process. It serves to help answer two questions ‘how might diagnostic laboratory-based disease surveillance data on the cattle population in Alberta be biased as it is private mixed and cattle veterinarians who in part determine which cases are submitted to diagnostic laboratories?’ and ‘how can we enable and motivate private cattle veterinarians in Alberta to participate in pre-diagnostic disease surveillance initiatives?’.

In chapter 6, I provide conclusions and presents ideas for future research into pre-diagnostic surveillance initiatives in the animal population.

Figure 1.1: Relationship between environmental drivers of infectious disease and health outcomes in humans and animals (adapted from Rabinowitz et al., 2008)

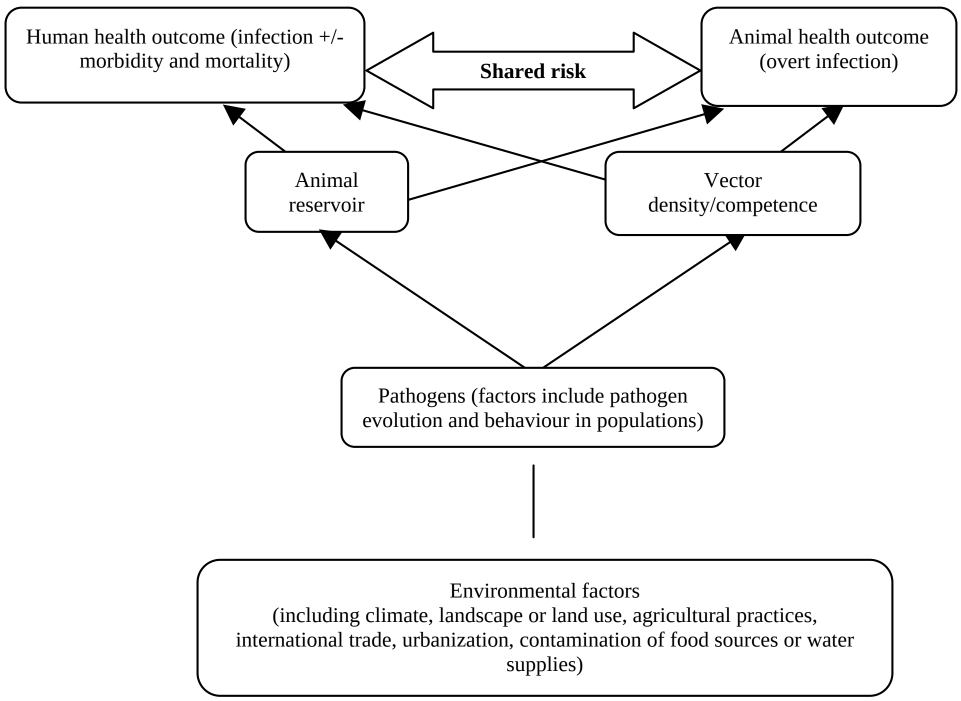


Figure 1.2: The surveillance process (adapted from Wagner et al., 2006)

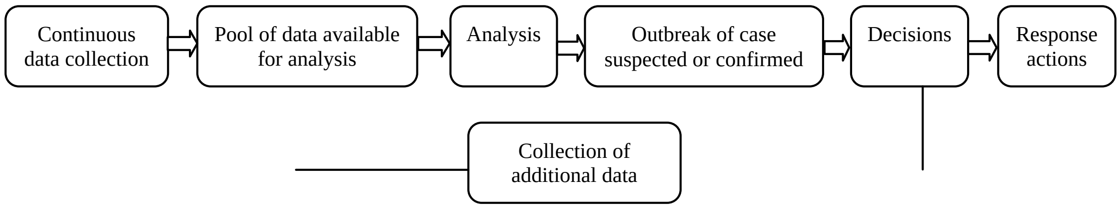


Figure 1.3: Diagnostic laboratory-based disease surveillance of clinical case submissions from veterinarians (adapted from Tataryn et al., 2007)

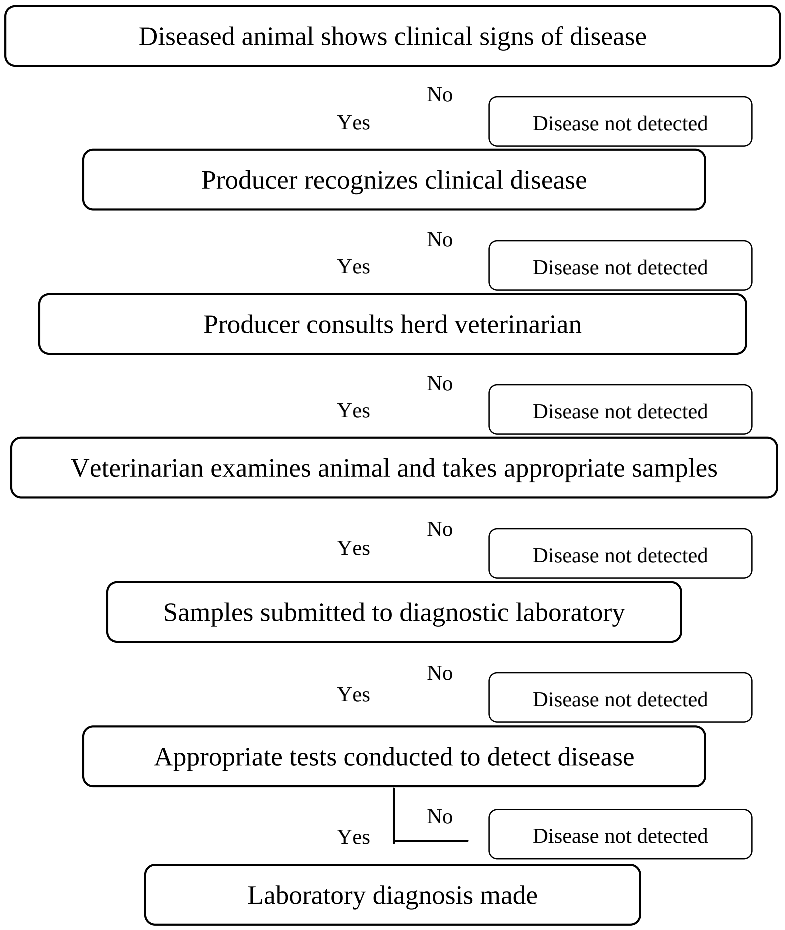


Figure 1.4: Timeline of human behaviours during occurrence of an infectious disease as they relate to potential data sources in a syndromic surveillance system (adapted from Mandl et al., 2004)

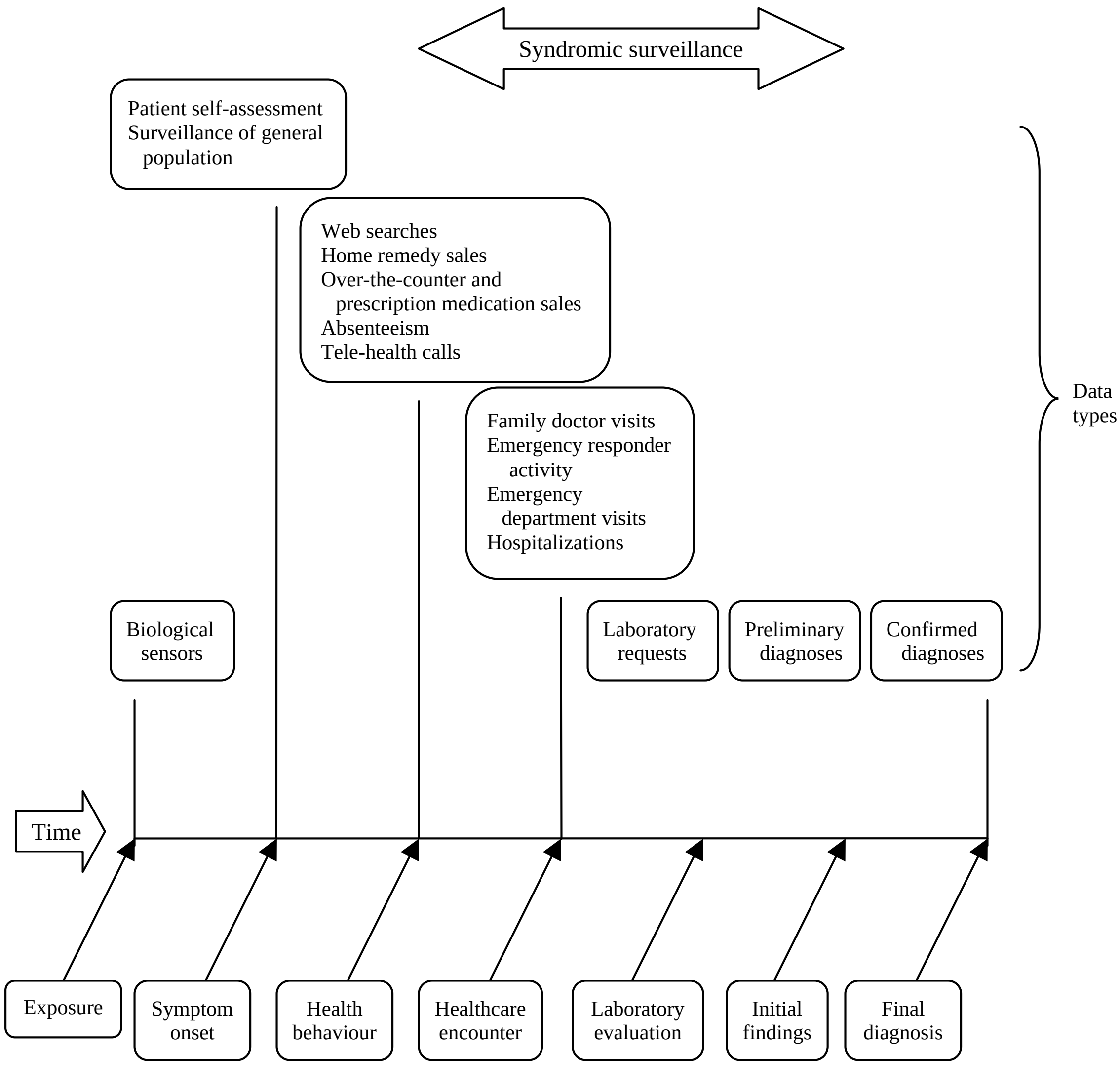
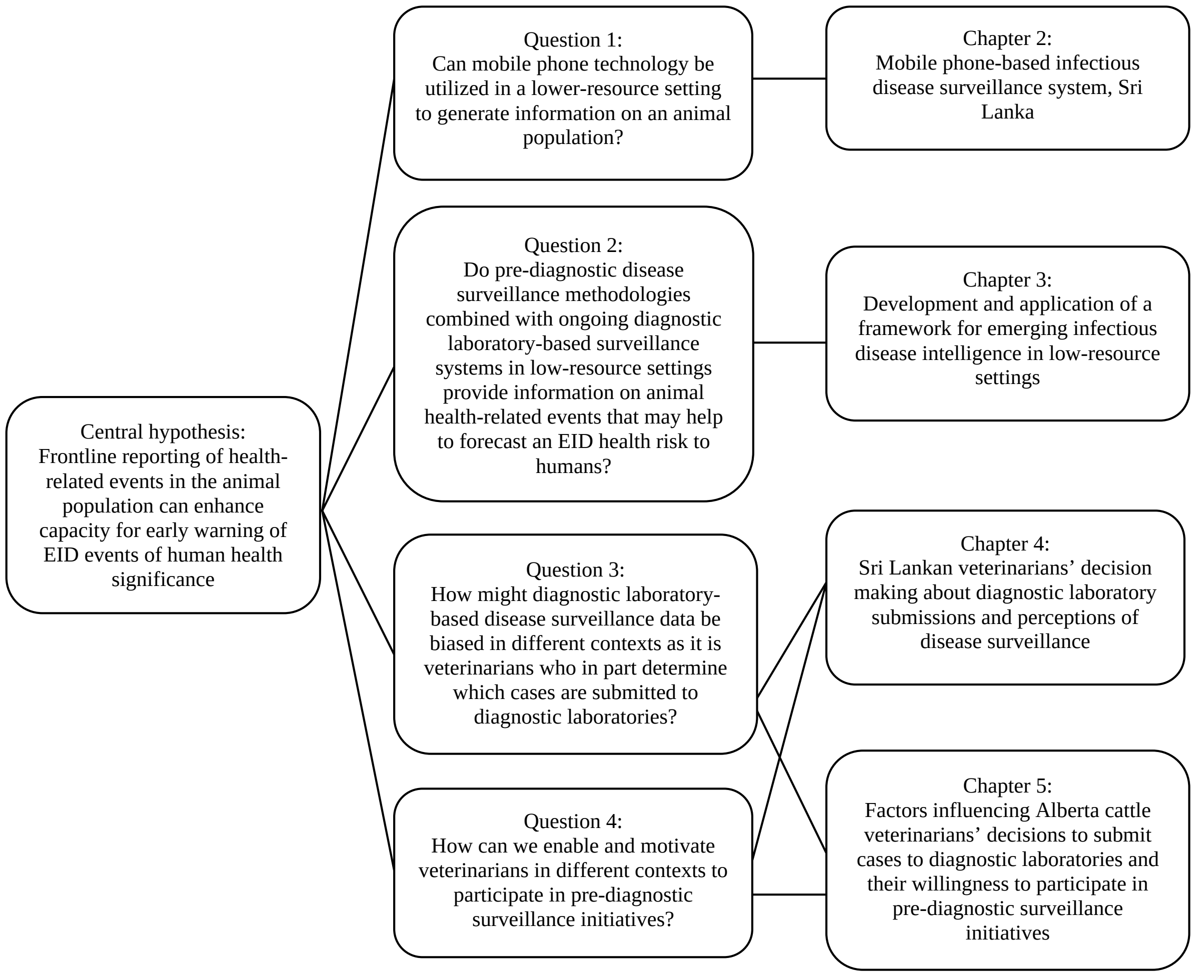


Figure 1.5: Central hypothesis, questions, and thesis structure



CHAPTER 2: MOBILE PHONE–BASED INFECTIOUS DISEASE SURVEILLANCE SYSTEM, SRI LANKA

Introduction

EIDs in animals and people are being identified more frequently than ever before, many in low-resource tropical countries, and this trend is expected to continue (Greger, 2007). Approximately 75 percent of EIDs in people are estimated to have come from animals (Greger, 2007), so there is much interest in the utility of animal health surveillance for prediction of human health risks (Halliday et al., 2007; Rabinowitz et al., 2005; Rabinowitz et al., 2009; Rabinowitz et al., 2008). The Canary Database, an online database named after the canary in the coalmine analogy, demonstrates the broad interest in this idea, containing over 1600 articles related to animal sentinels of zoonotic, environmental, and toxic effects on human health ("Canary database: Animals as sentinels of human environmental health hazards," 2009). In practice however, establishing links between animal and human health data has been difficult because data collected in animal and human health surveillance systems are collected at different resolutions, scales, and for different purposes. Human health surveillance is often based on aggregated diagnoses data obtained from standardized electronic medical records. Animal health surveillance systems vary widely (Doherr & Audige, 2001). Where electronic veterinary records are kept, data can be extracted to central databases and analyzed. However, in lower resource settings electronic recording of veterinary services is often not feasible.

In many human health projects in resource-challenged areas, mobile technologies have emerged as a promising solution for collecting, transmitting and analyzing human health information in a timely fashion (Bernabe-Ortiz et al., 2008; Diero et al., 2006; Missinou et al., 2005). In Peru, a mobile phone-based surveillance system has been used for early detection of infectious disease outbreaks in the Peruvian Navy (Soto et al., 2008). In Africa, the Satellife project has been employing mobile data collection devices for over two decades in human health surveys, and currently a project is underway using mobile phones and wireless technology in disease surveillance in Uganda (Mobile Active, 2008). Many United Nations health and development projects in Africa now employ mobile phones for collection of field data (Vital Wave Consulting, 2009). However, the authors are not aware of any examples of mobile phone-based disease surveillance to support an animal-based EID system in a lower resource setting.

In response to these challenges we have developed the IDSAS, a mobile phone-based surveillance system targeted at animal populations in lower resource settings. A pilot version of this system was implemented in January 2009 in partnership with the Department of Animal Production and Health (DAPH) in Sri Lanka. The objective of this system is to collect animal health information from field veterinary surgeons (FVSs) in a timely fashion in order to establish baseline patterns in animal health. By establishing baseline patterns in animal health conditions via regular electronic surveillance, we aim to build capacity to detect changes that may facilitate early detection of changing EID risks. Here we describe design and implementation of the system, present preliminary data that describe submission patterns, provide examples of some of the data that are being collected, and discuss obstacles and opportunities encountered during the first nine months of operation. The objective of this chapter is to highlight and generalize some of the lessons learned during the planning and implementation of the IDSAS in Sri Lanka.

Materials and Methods

Delivery of veterinary services in Sri Lanka

The provision of veterinary services in Sri Lanka is largely carried out by the DAPH, a national-level body responsible for control of livestock diseases, livestock research, animal breeding, and education in animal husbandry. Delivery of veterinary services is implemented through provincial level DAPH councils and field offices. Provinces are made up of districts, which are further divided into divisional secretariat (DS) divisions. Each DS division is assigned a FVS who is responsible for providing animal health services within that division.

System structure

Forty FVSs were recruited to pilot the IDSAS in four districts in separate provinces. The districts (Nuwara Eliya, Anuradhapura, Matara, Ratnapura) were selected to capture variation in livestock practices, climate, and environment (Figure 2.1).

Capacity for electronic collection and submission of data was developed in the IDSAS to decrease the time from detection to reporting of animal health events as compared to the existing method using mailed written reports. Internet access is limited in many parts of Sri Lanka but the cellular phone network is extensive. Mobile phones, namely Palm

Centro smartphones, were used as the data collection platform. Animal health surveys were developed using EpiSurveyor, a free and open-source software package developed for collection of public health data (www.datadyne.org). EpiSurveyor has been used extensively for human health data collection in Africa.

Surveys could be filled out in remote areas without cellular service and transmitted when the user was back in an area of reception. Decoupling data collection from transmission-capable locations greatly expanded the geographical range of the surveillance system. The location of each survey was also captured with global positioning system (GPS) software and an external receiver connected to the phone via Bluetooth. FVSs collected data throughout the course of their daily working activities (clinic and farm visits). Survey and GPS data were encoded and transmitted to a central database via email at the end of each day. A schematic overview of the IDSAS is presented in Figure 2.2.

Information structure

The pilot study was restricted to cases in chickens, cattle and buffalo. Every time a FVS visited a farm or saw a case in clinic involving one of these species they completed a survey within EpiSurveyor and recorded the location (for farm visits). While we aimed for daily submissions, our minimum target submission rate was two surveys, per FVS, per week. This was based on an estimate of the number of cases in chickens, cattle and buffalo seen on average by individual FVSs and work-related disruptions that could interfere with data submission (training, sick days, holidays etc.).

The first draft of the survey was based on the Alberta Veterinary Surveillance Network's Veterinary Practice Surveillance initiative (Government of Alberta, Agriculture and Rural Development, 2010). In the second stage, the survey was reviewed with a number of FVSs and government employees within the DAPH to ensure it was applicable to veterinary practice in Sri Lanka. The majority of questions were single answer, multiple choice-type questions, though additional comments were allowed in a free-text field. The survey was designed to minimize the time required to complete each survey, reduce the number of data entry errors, and permit simple and automated data analysis.

Data elements for each case included: date, location, type of operation, nature of visit (routine/non-routine), age and sex of affected animals, number on farm, number affected, clinical syndrome, clinical diagnosis, laboratory testing if applicable, and other species on the premises. A survey could contain up to three cases if all three species were present on a farm. FVSs selected from clinical syndromes outlined in Table 2.1. Within EpiSurveyor each syndromic grouping was linked to a list of clinical diagnoses.

Reporting and data analysis

Data reported here represent the experience of the IDSAS from January 1, 2009 through September 30, 2009. Weekly surveillance reports containing a list of cases were disseminated to project partners. These reports documented the following details pertaining to each case submitted during the previous week: date, species, reported syndrome, suspected clinical diagnosis, number of animals affected, number of animals on farm, number of dead animals, and a flag indicating whether samples were submitted to a laboratory.

Data completeness and submission patterns

Measures of data completeness used for the IDSAS at the planning and early implementation stages follow the guidelines set out by Lescano et al. (2008). In the planning stage it is important to assess the burden placed on data collectors to determine if data can be collected with existing resources. The IDSAS data collection procedure involved separate software programs for animal health surveys and GPS data collection. These data were linked via a common identifier entered by FVSs at the time of survey completion. To explore the linkage between survey and GPS data, we report completeness for surveys, GPS points, and linked survey-GPS records. We also report the percentage of surveys with a linked GPS point. As FVSs work six days of the week, we expect a day-of-the-week effect and therefore examine variation in survey submission by day of the week. Finally, we examine weekly submission counts to determine temporal patterns. We fit a linear trend model to the weekly counts to determine the average change in submissions per week.

Statistical surveillance

Digital storage of data that otherwise might not be captured allows more sophisticated statistical analysis. To demonstrate how the IDSAS database could be used in an outbreak detection context, we present an example of statistical surveillance using the total number of weekly surveys submitted by participating FVSs as an indicator for unusual animal health events. We use these data in a prospective temporal surveillance cumulative sum (CUSUM) statistic implemented in the statistical software package R (Höhle, 2007). The CUSUM measures accumulations of extra variance in a sequential framework, and alarms are signalled when the statistic exceeds a specified threshold. Parameters are required for the expected value, the reference value k, and the alarm threshold h. We estimated values for k and h based on an expected false positive rate of one every 52 weeks, to detect a change two standard deviations above the reference value. We evaluated two baseline scenarios: the mean of the first 14-week period, and a set value of 100 surveys per week. Analysis was carried out weekly beginning at week 14 until the end of the study period.

Caseload and case profile

The distribution of cases seen is presented by species and district. We also present the frequency of the five most commonly reported syndromes for each species.

Assessing system implementation

The experience of implementing the IDSAS provides lessons for future surveillance projects in lower resource settings. We synthesize some of the key lessons learned during this phase of the IDSAS based on technical, financial, political, and ethical/societal/cultural considerations (Chretien et al., 2008).

Results

Data completeness and submission patterns

The IDSAS was operational for 273 days. During this period, 3981 unique surveys were submitted to the system by participating FVSs. This corresponds to approximately 99 surveys per FVS over a 9-month period (11 per month), above our intended submission target minimum of 2 submissions per FVS per week. During this period, 96% of days had at least one conducted survey. The total number of unique GPS points submitted was 1650. Of these, 1172 (71%) were linked to an associated survey. Of the total days under surveillance, 76% had GPS data collected, and 64% had both GPS and survey data recorded. Informal discussions with many FVSs revealed that it took about one minute to complete an animal health survey, and one minute to collect a GPS point once the IDSAS had been in place for 6 months.

Temporal patterns in submissions are presented in Figure 2.3. In general, there was an increasing overall trend. The linear trend model revealed a significant weekly increase in submissions of 1.65% ($p < 0.001$, R2 = 0.31). The trend was also characterized by large variation (coefficient of variation = 3.01), with a large drop (39 surveys) in submissions in week 14. Day-of-the-week variation was present in submissions as expected, with weekly survey counts totalling 306 on Saturdays and 326 on Sundays, while during the week totals ranged from 515 to 695.

Statistical surveillance

Based on parameters described above, reference value k was estimated at 2.6 and the threshold value h was 4.1. Using week 14 as a baseline, 84 weekly visits were expected, which in the CUSUM analysis flagged an alarm at week 26 and weeks 30 through to the end of the study period (week 38). Using the expected value of 100 weekly visits, alarms were signalled from weeks 31 through 38.

Caseload and case profile

Out of 3981 surveys submitted during the 9 months of operation, 3150 cases were reported (i.e., reported an animal health issue). The majority (83%) of cases were seen in cattle, followed by chickens and buffalo (Table 2.2). These were mostly from an area known to contain a large number of dairy cattle operations. Production-related syndromes were the most commonly reported across all species, with decreased feed intake/milk production most prevalent in cattle and buffalo, and decreased egg production/weight gain/appetite in chickens (Figure 2.4). In buffalo, markedly higher gastrointestinal and lameness submissions were noted relative to other syndrome groupings. Gastrointestinal signs were common in Anuradhapura across all species. Cases in chickens were found predominantly in Ratnapura, where there is a large number of poultry operations. The syndrome profiles for chickens were similar across all districts (Figure 2.4).

Alerts identified by the IDSAS

There was one instance in which suspected cases of ‘Black quarter’ (*Clostridium chauvoei*) were identified at the time of review of the weekly report. As the DAPH was made aware of the cases shortly after they were identified by the FVS they were able to confirm that the FVS collected tissue samples for diagnostic testing. This increased information flow would not have been possible under the DAPH surveillance program as written reports of suspected cases from FVSs are received on a monthly basis and each must be reviewed individually to identify suspected cases of a particular disease of interest. Additional statistical alerts generated by analysis could be evaluated, as part of the objective of the IDSAS is to establish the baseline caseload burden in areas under surveillance.

Assessing system implementation (Table 2.3)

Technical considerations

Technical barriers were a major challenge during implementation of the IDSAS. The system introduced new data collection requirements for FVSs. Using cell phones for data collection required training and ongoing technical support.

Financial considerations

The main costs of the system were associated with data collection hardware. Each phone and GPS extension set cost approximately 500 CAD. This cost may have been reduced if phones were available for purchase locally. Proprietary software options with different hardware requirements were available but rejected as recurring licensing costs could not be sustained while hardware was a one-time expense. Though data plans are an ongoing cost, the size of files generated by the IDSAS is typically less than one kilobyte. The cost of data transmission per user per month in Sri Lanka is less than five dollars CAD.

Investments in hardware and human resources for data collection can be quickly recouped as these resources are extendable to many other fields in which the Sri Lankan government is involved (e.g., human epidemiology, environmental assessment, disaster planning).

Political considerations

Political support has been the most important factor in the successful implementation and operation of the IDSAS. Animal health reporting standards set by the World Organisation for Animal Health (OIE) require member countries to report about a suite of animal diseases. The introduction of a new surveillance system as part of a research project resulted in initial confusion about how such a system could fit within existing surveillance networks. A major challenge in the implementation of the IDSAS was drawing the distinction between the IDSAS as a research project and the national animal disease reporting system of the DAPH. Negotiating this challenge was possible with support from key figures in the government and the University of Peradeniya.

Ethical, societal, and cultural considerations

During the design and early implementation of the IDSAS, concerns around privacy and data security were addressed promptly as they arose. No information pertaining to animal owners was collected. No personal identifiers from FVSs were linked to survey submissions.

Discussion

The IDSAS has been developed based on the premise that monitoring animal health can provide information for early warning of EIDs and changing disease patterns. Preliminary results presented here demonstrate significant enhancement of existing technological infrastructure. Equipping FVSs with the necessary means of communication enables timely case submission, and the skills to make use of these tools has helped to build further capacity in animal health surveillance. Weekly reports document increased knowledge and information flow between Sri Lankan animal health stakeholders. Finally, through the IDSAS significant progress has been made toward establishing baseline patterns of suspected diagnoses and syndromes in cattle, buffalo, and chickens.

Uptake of the IDSAS over its initial 9 months of operation resulted in data generation from almost 4000 interactions between FVSs and the animal population. Increasing use of the IDSAS over time is also illustrated by a positive linear trend in submissions. Statistical surveillance of the number of surveys submitted by FVSs revealed that an upward shift in submissions occurred around week 30. The overall trend is likely due to FVSs gaining competency with the technology while the shift is likely due to a combination of reduced number of submissions in weeks 14-16 related to training and examinations and the final stages of the civil war in weeks 19-21, followed by retraining in week 23. The alarms signalled by the CUSUM analysis illustrate the importance of modeling the expected value when using surveillance statistics.

The distribution of cases highlights one of the challenges with this type of data, and indeed many types of surveillance data, and that is how to interpret variability in cases in the absence of data about the population at risk. The high number of cattle cases in Nuwara Eliya was expected given prior knowledge of the large number of milk-producing cattle in that region. Yet the distribution of cases would only be expected to reflect the true disease burden in the population if the likelihood of a veterinarian seeing a case in a given species were proportional to the underlying disease distribution in the 3 species in each area. For example, in Nuwara Eliya, cattle raisers might be more inclined to call their veterinarian in the event of a sick cow compared to a sick chicken. The solution to this problem, if the aim is to establish a predictive, prospective disease surveillance system, is establishing normal patterns of case submission for the population. For this to be realized, this system (and others) must be maintained over a period of time within the same geographical areas.

One of the barriers to implementation of the IDSAS in its current form is the cost of hardware and the need for a server administrator. However, since the pilot project in Sri Lanka a new version of EpiSurveyor has been released. A number of important changes have been made: the software now runs on a wide range of standard mobile phones; data can be uploaded to servers administered by datadyne.org as well as analyzed on the phones themselves; and GPS data can be collected within Episurveyor. These changes drastically reduce the costs of implementing mobile surveillance: the cost per mobile phone unit reduces substantially and there is no need for governments to purchase and administer their own database.

At this time the DAPH has decided to incorporate the IDSAS into its ongoing disease surveillance efforts and the system is being run on two parallel servers, one at the DAPH and the original server that hosts the IDSAS. After this transition period the system will continue to run only on the DAPH server and may be modified to suit additional surveillance priorities (e.g., goats, swine). The DAPH will not be providing incentives to FVSs for participation. It would be valuable to solicit further FVS review once the system has been transitioned, and to monitor submissions long term.

Beyond the data collected by the IDSAS to date, this research demonstrates that, through developing human capital and technological capacity, novel surveillance methods can be implemented that are feasible and acceptable in lower resource settings. These considerations are supplemented with lessons for planning and implementation of surveillance systems. It is hoped that by disseminating the results of this initiative other governments will be able to tailor the IDSAS to their particular animal health surveillance needs. The collaboration and relationships established in this project should yield further benefits through technical training and pooling of human and physical resources for sustaining and promoting veterinary public health in Sri Lanka. Additionally, the advantages of electronic health surveillance using mobile data collection afforded by the IDSAS are immediately known to important administrative figures that can affect change in other areas of animal and human health policy and planning.

Table 2.1: Syndrome groupings used in animal health surveys in the Infectious Disease Surveillance and Analysis System

Species	Syndrome groupings
Buffalo and Cattle	Abortion/birth defect
	Ambulatory lameness
	Decreased feed intake/milk production
	Gastrointestinal signs
	Neurological signs
	Recumbency
	Peripheral edema/misc swelling
	Reproduction/obstetrics problems
	Respiratory
	Skin/ocular/mammary
	Sudden or unexplained death
	Urologic
	Vesicular/ulcerative
	Other
Poultry	Ambulatory
	Decreased egg production/decreased weight gain/decreased appetite
	Neurological/recumbent
	Peripheral edema/misc swelling
	Respiratory
	Skin/ocular
	Sudden or unexplained death
	Other

Table 2.2: Total number of cases in cattle, buffalo, and chickens in each of the four study districts covered by the Infectious Disease Surveillance and Analysis System from January 1, 2009 to September 30, 2009

District	Cattle cases	Buffalo cases	Chickens cases	Total
Ratnapura	548	106	146	800
Matara	388	62	55	505
Nuwara Eliya	1095	16	11	1122
Anuradhapura	596	70	57	723
Total	2627	254	269	3150

Table 2.3: Lessons learned for planning and implementing surveillance systems in lower-resource settings

Considerations for surveillance in lower resource settings	The IDSAS experience	Generalized lessons
Technical	Cell phones permitted timely collection and transmission of data to the surveillance system. Touch screen interfaces were new technology for field veterinarians.	Use of familiar technologies such as basic cell phones will minimize training time. Cell phones enable timely data collection and transmission.
	Ongoing training was essential. A local research assistant made training more effective, in particular because field veterinarians could learn the system in their native language.	Developing local expertise at the project outset is invaluable for ensuring sustained technical and logistical support.
Financial	Hardware required for data collection was relatively inexpensive but much more expensive than hardware available in Sri Lanka. Importing cell phones for the project was challenging.	Where possible, hardware that is locally available should be used.
	Open-source software was used when possible, eliminating licensing as a recurring cost but requiring more training and technical skills to maintain.	Open-source software options should be selected over proprietary options to reduce costs and generate technological capacity.
Political	External funding covered the initial hardware and software costs.	Obtaining external financial support to cover the initial investment required will make implementation more feasible.
	Support at the provincial level was critical for engagement of field veterinarians.	Garnering support at all levels of government is critical at the early implementation phase.
	Engagement of key political stakeholders was essential to alleviate fears about potential for harm caused by novel types of surveillance data.	Early in the design process it is important to discern what the outputs of the system will be and their added value.

Considerations for surveillance in lower resource settings	The IDSAS experience	Generalized lessons
Ethical, societal and cultural	Government officials were initially concerned about data security.	Build appropriate data security into all components of the system.
	It was late in the implementation phase when government stakeholders recognized the potential for additional data uses.	Examples of additional uses of data obtained will generate support for new surveillance initiatives.
	At the onset of the project, field veterinarians were sceptical about the usefulness of data generated by the IDSAS. However, over time they envisaged how the outputs could be used in disease surveillance and in improving their daily veterinary duties.	Adoption of novel surveillance methods requires user acceptance and new technical skills. Time and experience will enable this transition to occur.
	Many farms are geographically isolated making access to field veterinarians difficult.	Quality and quantity of data from surveillance systems are affected by the ability of an animal owner to access animal health services.

Figure 2.1: Study districts within Sri Lanka where field veterinarians participating in the Infectious Disease Surveillance and Analysis System collect data on animal health seen during their daily working activities

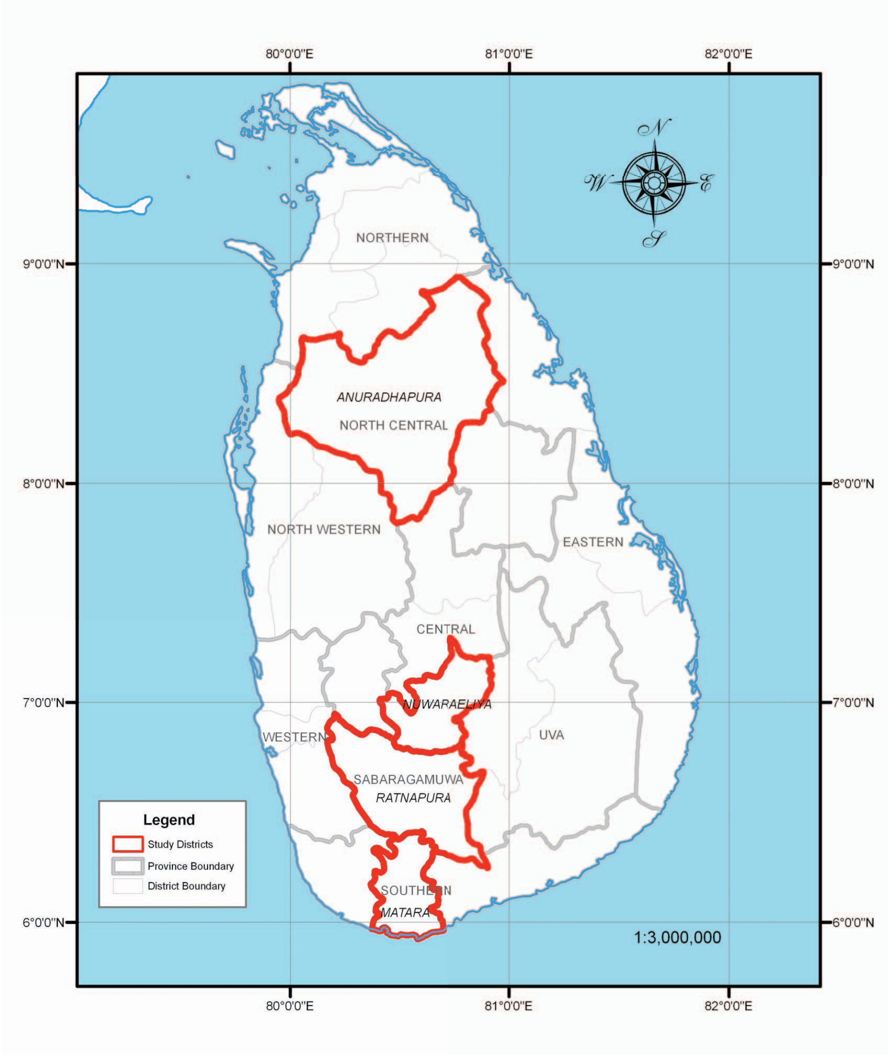


Figure 2.2: Schematic overview of the major components of the Infectious Disease Surveillance and Analysis System

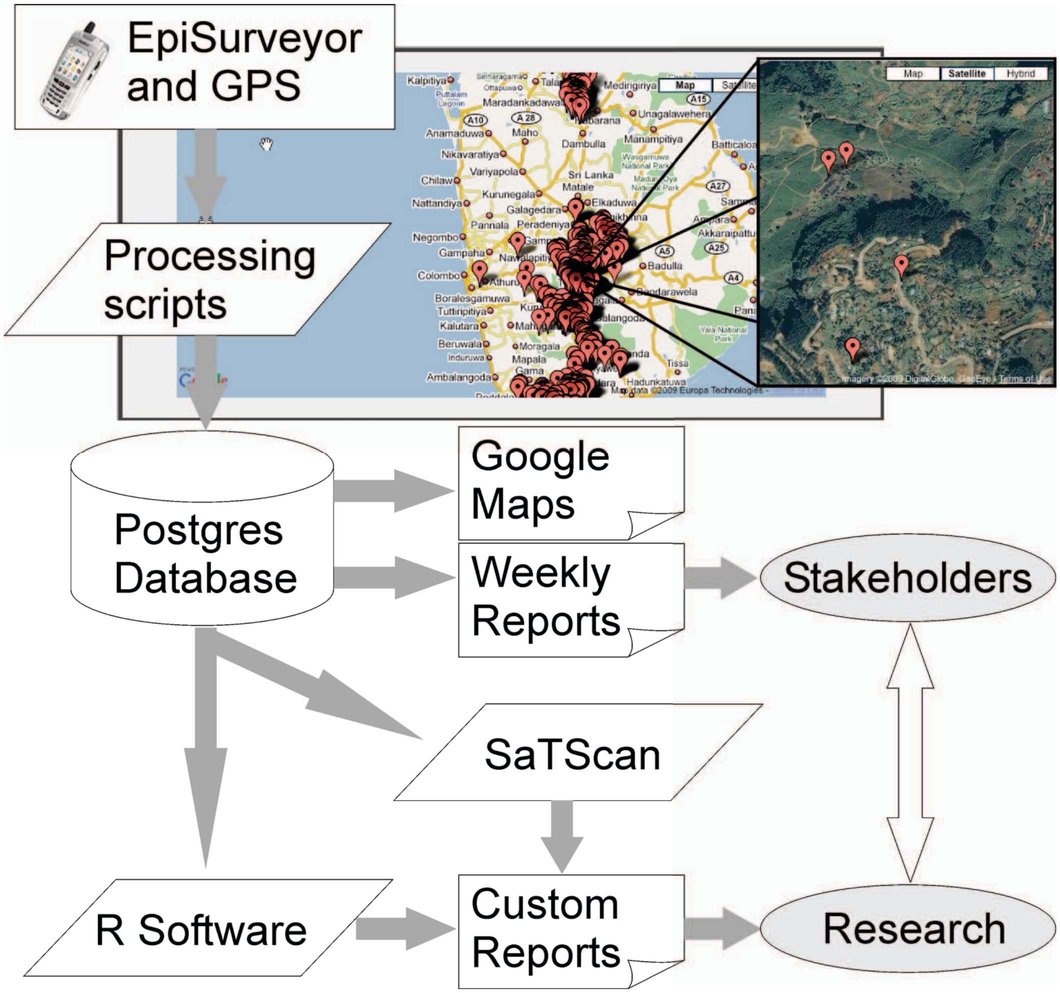


Figure 2.3: Number of surveys (black), GPS points (red) and linked survey-GPS (blue) submissions to Infectious Disease Surveillance and Analysis System from January 1, 2009 to September 30, 2009

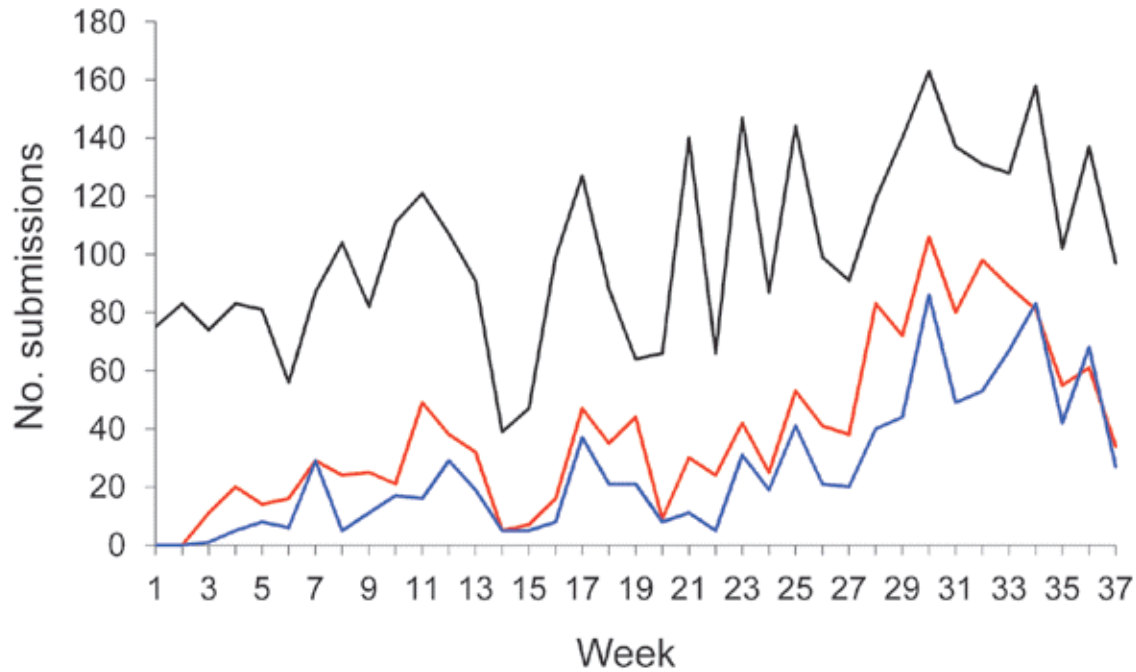
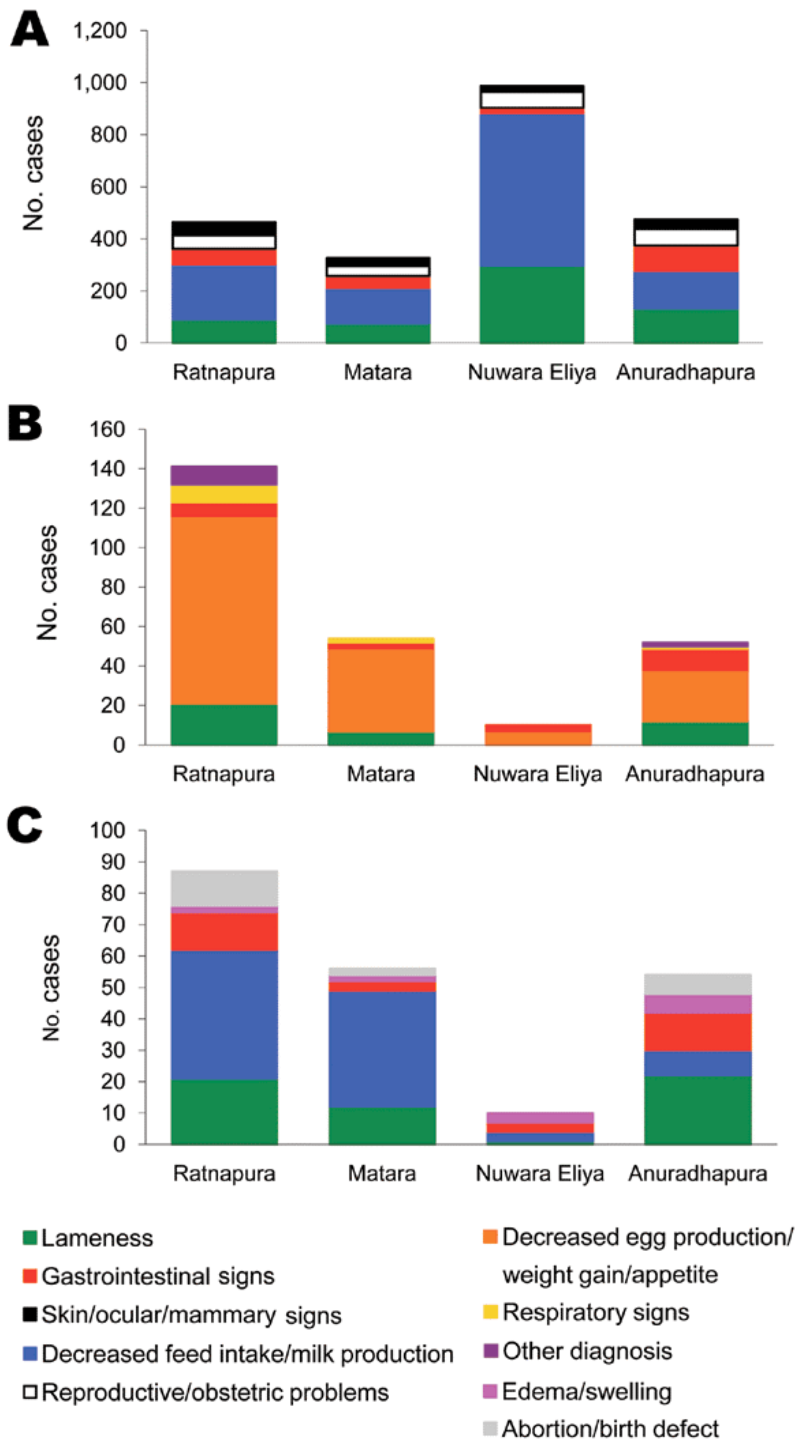


Figure 2.4: Frequency of syndrome groups seen by field veterinarians in (a) cattle, (b) buffalo, and (c) chickens in each of the four study districts part of the Infectious Disease Surveillance and Analysis System from January 1, 2009 to September 30, 2009



CHAPTER 3: DEVELOPMENT AND APPLICATION OF A FRAMEWORK FOR EMERGING INFECTIOUS DISEASE INTELLIGENCE IN LOW-RESOURCE SETTINGS

Introduction

The landscape of infectious disease risk has changed dramatically over the last forty years. A number of new infectious diseases have emerged, catching the global public health community off guard. The rate of emergence has been increasing and this trend is expected to continue (FAO, WHO, & World Organisation for Animal Health [OIE], 2004; Greger, 2007; Jones et al., 2008). Infectious diseases are deemed ‘emerging’ if they have only recently arisen or if they are previously known diseases that are increasing in incidence or geographic or host range (S. Morse, 2004). It is estimated that close to 75 percent of new EIDs in humans have arisen in animals (Jones et al., 2008), making animal surveillance an important part of EID preparedness (Rabinowitz et al., 2008). Forces driving emergence and spread of these diseases include: increasing demand for animal protein; expansion of intensive animal agricultural systems; long-distance transportation of live animals; bush meat consumption; and anthropogenic landscape changes (Daszak, Cunningham, & Hyatt, 2001; Ka-Wai Hui, 2006; Patz et al., 2004). As the size of the global population increases so too will these forces (Jones et al., 2008) and therefore reliable means of forecasting the risk of future EID events are in demand (Daszak, 2009).

When the risk of future EID events is mapped, it is highest in areas at lower latitudes where many countries have marked resource constraints (Jones et al., 2008). These countries have limited resources: in many cases they lack the transportation, diagnostic laboratory, and human infrastructure required to perform many of the surveillance techniques developed in high-resource countries and they have limited resources to allocate to EID surveillance (L. May et al., 2009). Therefore, research in the area of EID surveillance should focus on developing techniques and methods that are adaptable to local conditions, especially those in high-risk areas (e.g., Chretien & Lewis, 2008; Chretien et al., 2008; L. May et al., 2009).

Public health surveillance is defined as the 'ongoing, systematic collection, analysis, and interpretation, and dissemination of data about a health-related event for use in public health action to reduce morbidity and mortality and to improve health' (German et al., 2001). Public health surveillance provides support to public health and policy decision-making (Stachenko, 2008; Thacker, Stroup, & Rothenberg, 1995) . In 1988 the CDC published the Guidelines for Evaluating Public Health Surveillance Systems to 'ensure problems of public health importance are being monitored efficiently and effectively' (CDC, 1988). Ultimately, the aim of a surveillance system evaluation is to determine if a given system is serving a useful public health function and meeting the objectives defined as part of the evaluation process (CDC, 1988). Attributes defined as necessary for the evaluation of a surveillance system by the CDC include simplicity, flexibility, acceptability, sensitivity, predictive positive value, representativeness, and timeliness (CDC, 1988). In 2001, the CDC published updated guidelines in part because of the need for 'changes in the objectives of public health surveillance to facilitate the response of public health to emerging health threats' (German et al., 2001). They differ from the 1988 guidelines in that data quality and stability are included as additional system attributes for evaluation and there is discussion of the implications of electronic storage, management, and transfer of surveillance data (German et al., 2001). Updates from 2004 stress timely data collection and analysis for detection of infectious disease outbreaks (Buehler et al., 2004). These guidelines have played a vital role in the development, implementation, and maintenance of many surveillance systems (e.g., Doroshenko et al., 2005; Huaman et al., 2009; Josseran et al., 2010; Lombardo et al., 2004).

Surveillance in the animal health field has historically targeted submissions to diagnostic laboratories, much like in the human health field, where the aim is to make an etiological diagnosis (Hueston, 1993). This type of surveillance is limiting with respect to identifying EID events: the etiological agent may be previously unknown, significantly delaying a diagnosis (Wagner et al., 2006); diagnostic technologies may be costly and have limited availability, particularly in rural and low-resource settings, severely restricting the sensitivity of systems (Lemon, Hamburg, Sparling, Choffnes, & Mack, 2007); and clinicians may encounter new diseases that mimic common diseases and therefore attribute cases to an enzootic agent, precluding the need for diagnostic laboratory support (e.g., Chua et al., 2000). When new pathogens are identified, often there are no data about exposure to determine the risk they pose to human health (Kuiken et al., 2005). These limitations indicate that laboratory-based surveillance often fails to capture the information required to adequately forecast the risk posed by animal health-related events (Kuiken et al., 2005).

Due to the changing EID landscape and limitations of laboratory-based surveillance, there is a desire to develop, implement, and evaluate surveillance systems that use other forms of animal data such as movement patterns (Ortiz-Pelaez, Pfeiffer, Soares-Magalhaes, & Guitian, 2006) and live-market sales (Fevre et al., 2001; Fevre et al., 2006) to identify events that could forecast an emerging health risk to humans (R. A. Weiss & McLean, 2004). The reason for seeking out new data sources for animal-based surveillance is two-fold: there is a need to detect animal health events as early as possible, and there is a need to consider events in context to determine their significance as a human health risk. Identifying new sources of animal health data that enable early recognition of emerging human health risks remains a key challenge to EID surveillance (Scotch, Odofin, & Rabinowitz, 2009).

In order to contain future EID outbreaks, events that precede such outbreaks will have to be identified to allow for a response to occur before there is widespread exposure (Daszak, 2009). As a result, EID surveillance methods have been developed in the human health field that target alternative data sources, though much of this work has been done in high-resource countries (Effler et al., 1999; Wagner et al., 2006). In many cases these methods are made possible through technological advances, including ubiquitous Internet access and electronic record keeping. It is hoped that these new systems will facilitate more timely identification of EID events (Wagner et al., 2006). The objectives of these new systems can differ markedly from those upon which the CDC's evaluation guidelines were based. For example, in more traditional surveillance systems the goal is often to identify all cases of a particular infectious disease, or to get a sense of the true prevalence of disease in the population. With surveillance systems whose purpose is to detect a change in EID risk, the objective at least initially is often not to enumerate individual cases of an infectious disease, but rather to detect a change in status of the population that could indicate an impending EID event or identify the index case. There are also additional challenges specific to EID event detection: while the rate of EID events is increasing, and historically these events have had huge impacts on human and animal health and economies (Thompson et al., 2002), the incidence of EID events globally remains very low. As a result, even if a surveillance system has both high sensitivity and specificity, the positive predictive value will approach zero, and quantitative evaluation of the system will result in a ratio of false positives to true positives deemed unacceptable (MacDonald, 2003). Alternative means of evaluation that have been suggested and performed include: determining how good the system is at detecting a known, endemic disease or clinical syndrome grouping, often compared to an alternative or previously existing system; evaluating the qualitative attributes of the system, again making some comparison to an alternative or existing system; and performing a study in which a simulated outbreak is inserted into an existing surveillance data stream (MacDonald, 2003). However, these alternatives are limited in that they fail to provide information to stakeholders about the ability of a given system to detect a real-world EID event or change in EID risk (MacDonald, 2003).

Surveillance systems that use animal health and disease occurrence data have been developed, in many cases by adapting methods from the human health field; however, the majority operate in high-resource countries (Vrbova et al., 2010). Very few have undergone a formal evaluation process, and in cases where there has been an evaluation most often only a subset of the CDC's system attributes is considered (Vrbova et al., 2010). One of the challenges in evaluating these types of systems is that the purpose of using animal data for surveillance of public health risks from EIDs is to forecast risk to people. In contrast, the CDC's guidelines were based on surveillance systems that aimed to identify human cases within human data.

EID surveillance that uses data other than clinical human cases can be considered risk factor surveillance (Stark et al., 2006). Work in the area of detecting a change in risk is not limited to the field of EIDs. With recently heightened concerns around terrorism, there has been extensive research and investment in military intelligence (Liao, Sun, & Wang, 2003). The purpose of a military intelligence agency is to 'watch and monitor all possible sources of threats and transform that information into valuable intelligence content for implementing military operational activities' (Liao et al., 2003). The desire of military intelligence to find unknown and difficult to quantify 'threats' is analogous to the challenge of EID detection. Effective surveillance systems enable decision makers to continually assess the situation and mount timely reactions to threats as they arise, or in essence 'deploy the troops' efficiently and effectively. In the military context, surveillance equates to the monitoring of any data that are collected from reconnaissance, while intelligence involves analyzing those data and transforming them into usable content for planning and decision-making (Liao et al., 2003). The same distinction between surveillance and intelligence in EID risk forecasting might have considerable value for systems evaluation.

In this chapter I propose an EID intelligence framework informed by published literature from the fields of surveillance, epidemic intelligence, and military intelligence. The purpose of this framework is to define clearly the information that is required to forecast the EID risk that animal health-related events pose to people. The intent is to build a framework that can be used during the design of animal surveillance systems that aim to provide EID early warning and during the evaluation of systems to assess their ability to aid in EID early warning. I then apply this framework to the IDSAS, a mobile phone-based animal health surveillance system that was piloted in Sri Lanka, and Sri Lanka's animal diagnostic laboratory-based surveillance infrastructure. I conclude that a mobile phone-based surveillance system could serve to supplement existing diagnostic laboratory-based surveillance in Sri Lanka and has the potential to contribute to EID intelligence in this low-resource setting.

Materials and Methods

Proposed framework for EID intelligence

A scoping review of published evaluations and criteria for surveillance, epidemic intelligence, and military intelligence was conducted to identify common experiences, opinions, and features of an information system that could serve as a framework for EID intelligence. In this chapter the word 'framework' applies to the basic structure underlying the EID intelligence concept. Because there are no published evaluations of emerging zoonoses surveillance systems that use animal disease data (Vrbova et al., 2010), an evidence-based framework could not be developed, and therefore commonalities in experiences and opinions expressed in the literature were sought. Keyword searches were done in PubMed, Google Scholar, and Google using combinations of the following phrases: infectious disease surveillance, surveillance system, evaluation, epidemic intelligence, and military intelligence. This was not a systematic review but rather a scoping review of the literature intended to identify common themes and concepts. A scoping review is similar to a systematic review in that it is a method used to organize and describe a body of literature (Brien, Lorenzetti, Lewis, Kennedy, & Ghali, 2010). However, with a systematic review there is an attempt to answer a clearly defined research question and part of the review process involves assessing the quality of publications (Brien et al., 2010). In contrast, scoping reviews serve to examine the extent, range , and nature of research within a given field and do not necessarily require in-depth examination of literature or any type of quality assessment of publications themselves (Brien et al., 2010). Attributes and functions common across the systems found in the literature were used to identify features and elements of the proposed framework. Commonalities between human and animal health fields and reoccurring discussions around challenges authors encountered during surveillance system design, implementation, utilization, and evaluation were used to help identify specific system attributes for EID intelligence.

One author was responsible for retrieving and reviewing the articles. No attempt was made to assess the quality of the papers. English language titles and abstracts retrieved were read and articles were selected if they satisfied one of the following criteria: 1) they reviewed and synthesized findings across the subjects of surveillance, surveillance systems, surveillance system performance and evaluation, animals as sentinels, and infectious disease outbreaks; 2) they provided explanation supported by literature for essential surveillance system characteristics; 3) they detailed considerations in surveillance system design and implementation; or 4) they defined and/or detailed epidemic intelligence or military intelligence. The *system features* associated with early warning and intelligence were organized and synthesized hierarchically in a narrative form by the author and Dr. Craig Stephen, Doctoral Supervisor and an experienced surveillance epidemiologist. Common objectives of early warning systems were identified as the system features of an EID intelligence system. The defining characteristics of the system features were identified as *elements*. For each element, common *goals* were sought that served as identifiable outcomes of early warning or intelligence systems. The *components* of the system were defined as the capacities, resources or infrastructure associated with delivery of these goals. Finally, *attributes for design and/or evaluation* of each component were identified as measurable features of each component that would allow one to determine if the components were in place to meet the objectives of an EID intelligence system. System features, elements, goals, components, and attributes, as well as their key references, were organized into a table to clearly define the framework, document the scoping review process, and illustrate the hierarchical structure.

The Infectious Disease Surveillance and Analysis System (IDSAS)

In Chapter 2 a detailed description of design and implementation of the IDSAS is provided. The IDSAS enabled participating FVSs in Sri Lanka to submit data pertaining the clinical cases they assess as part of their daily practice. It was established in collaboration with the DAPH, the national-level body responsible for control of livestock diseases, livestock research, animal breeding, and education in animal husbandry in Sri Lanka. Veterinary services are delivered through provincial-level DAPH councils and field offices. Provinces are made up of districts, which are further divided into DS divisions. Each DS division is assigned a minimum of one FVS that provides animal health services. In the four participating districts in Sri Lanka (Anuradhapura, Matara, Nuwara Eliya, Ratnapura) the IDSAS employed forty FVSs to track syndromes and clinical diagnoses in cattle, buffalo, and poultry. Each survey submitted by a FVS represented one visit to a farm or one examination in a clinic of at least one of the three species. Surveys were classified by routine visits (yes/no), presence or absence of an animal health issue, location of the case (clinic/on-farm), diagnostic samples submitted (yes/no), and gross post mortem examination (yes/no). When an animal health issue was present, cases were given a syndrome group and a clinical diagnosis. FVSs were given the option of classifying the cause of the animal health issue as unknown or other, in which case comments in a free-text field could be entered. There were a total of 17 syndrome groups for cattle and buffalo and 11 for poultry. Options for clinical diagnoses were based on the syndromic grouping selected. As each FVS is responsible for a known geographical area, geographic locations could be associated with each survey down to DS division level. FVSs were asked to submit surveys via email to a surveillance database daily. Weekly reports containing a list of cases were disseminated to project partners.

Diagnosed laboratory-based surveillance in Sri Lanka

The DAPH carries out surveillance for OIE listed diseases and emerging animal diseases. The Veterinary Research Institute (VRI) operates under the DAPH and is the only national-level organization in Sri Lanka that provides veterinary diagnostic services. District-level laboratory diagnostics are provided by Veterinary Investigation Centres (VIC). They are located in fifteen of the twenty-five districts: Anuradhapura, Badulla, Hambanthota, Chillaw, Jaffna, Matara, Peradeniya, Rannala, Polonnaruwa, Ratnapura, Vaunia, Welisara, Kegalla, Nuwara Eliya, and Dambulla. One aim of the DAPH is to establish VICs in every district in Sri Lanka.

Diagnostic laboratory data are stored in paper format at the VRI and VICs. Diagnostic laboratory data from the geographical area covered by the IDSAS were compiled and digitized into a Microsoft Excel® spreadsheet. For each case, fields included: date; location from which the sample(s) were collected down to the DS division level; species; age of the animal(s); number of animals in the flock or herd; sex; number of samples collected; type of sample(s); test(s) performed; result of the test(s); agent(s) identified; and whether the test was performed as part of a government-initiated health program. The data presented cover the period of January 1 2000 through to December 31 2009.

Diagnostic laboratory data

In order to detail ongoing diagnostic laboratory-based disease surveillance in Sri Lanka, the availability of laboratory diagnostics was tabulated and descriptive statistics about submission patterns were calculated. The number of case submissions and laboratory tests performed for the area covered by the IDSAS, the average number of tests per year, the range, mean, and median number of tests per DS division over the 10-year period, and the percent complete for each of the submission fields were calculated. Only case submissions from the three species tracked by the IDSAS were included in order to compare the number of submissions between the two systems. Case submissions known to be from government-initiated health programs were excluded because they often entailed multiple visits to a small number of farms over a short period of time (weeks to a few months) to collect blood, fecal, and milk samples in order to test for a variety of pathogens. These programs are directed by VICs and do not reflect case submissions from FVSs.

Census of Agriculture data

The Agriculture and Environment Statistics Division of the Department of Census and Statistics is the national-level body responsible for collecting, processing, and disseminating information related to agriculture in Sri Lanka, including data on the livestock population by species, district and division. Estimates of the cattle, buffalo, and poultry populations from the geographical area covered by the IDSAS were collected during the year 2008. Agricultural census data were included to illustrate the use of multiple data sources, in particular how the IDSAS and census data could be used to calculate population- and farm-level case rates.

Information flow within the government veterinary services in Sri Lanka

In order to understand how animal health data moved from the field level through to the DAPH headquarters, individuals at all levels of the government veterinary services in Sri Lanka were contacted. Individuals were identified initially through research contacts within the DAPH and the Ministry of Livestock Development. Snowball sampling, a way of locating key informants through a network of associates (Patton, 2003), was then employed using the professional contact network of these preliminary research contacts to identify other key informants. All discussions took place in person. Topics of discussion included the animal health situation in Sri Lanka, the availability of diagnostic laboratory testing and supplies, handling of suspect cases of OIE listed diseases, sources of data, data handling, and dissemination of information. This interview process was not meant to be exhaustive, but rather to provide an understanding of information flow within the government veterinary services.

In order to explore the contribution of the IDSAS to surveillance data flow in Sri Lanka, the flow of information from the IDSAS was superimposed onto a flow diagram of existing veterinary infrastructure in Sri Lanka. Included are the VRI and VICs to illustrate how cases move through various levels of the diagnostic hierarchy, from reporting a case to a FVS, to making a clinical diagnosis, to submitting a sample for a diagnostic laboratory test, and finally reporting a result to relevant authorities.

Assessing the contribution of the diagnostic laboratory-based surveillance system and the IDSAS to EID intelligence in Sri Lanka

Data pertaining to the information collected, reporting completeness, and other features of the IDSAS and the diagnostic laboratory-based surveillance system were linked to the EID intelligence framework to explore the contribution of both systems to EID intelligence in Sri Lanka.

Results

Proposed framework for EID intelligence

There is a large body of literature that deals with surveillance, EID events, and surveillance systems in general. Detailed evaluation was restricted to a number of critical publications that synthesized main lessons (e.g., Burkom, Loschen, Mnatsakanyan, & Lombardo, 2008; Chretien et al., 2008; Christensen, 2001; C. Fraser et al., 2004; German et al., 2001; Halliday et al., 2007; Ka-Wai Hui, 2006; Kahn, 2006; Lescano et al., 2008; Mandl et al., 2004; S. Morse, 2007; Rabinowitz et al., 2005; Ribble & McLaws, 2007; Stephen & Ribble, 2001; Tataryn et al., 2007; M. C. Thurmond, 2003; Wagner et al., 2001; WHO, 2006a) . There were only a few key references available that define and describe epidemic intelligence (Kaiser, Coulombier, Baldari, Morgan, & Paquet, 2006; Paquet, Coulombier, Kaiser, & Ciotti, 2006) and military intelligence (Biermann, Chantal, Korsnes, Rohmer, & Uendeger, 2004; Liao, 2001; Liao et al., 2003). Common features derived from these sources indicate that EID intelligence must provide information early in the course of events and be capable of generating warning signals, and that associated with each warning signal must be some indication of risk posed by the event taking place. Table 3.1 presents the elements, goals, components, and attributes for evaluation linked to these common features. Key references are provided to detail the connection between the table and the reviewed literature.

Flow of animal disease data in Sri Lanka

An overview of existing disease surveillance infrastructure in Sri Lanka was merged with the IDSAS in Figure 3.1. The flow of data through levels of government veterinary services was derived from field-level interviews.

Summary of the diagnostic laboratory data

The current laboratory diagnostic capabilities of the government veterinary services in Sri Lanka are presented in Table 3.2. During the 10-year study period 1208 laboratory tests were performed on 1101 cases at the VRI and relevant VICs. This is equivalent to ~3.02 laboratory tests/DS division/year (0.25 tests per month). The tests per DS division ranged from 0 to 305 over the 10-year period, with a mean of 30.2 and a median of 7.5. Measures of diagnostic laboratory data completeness are presented in Table 3.3. The first diagnostic samples were processed at the VIC in Anuradhapura in January 2008; in Matara in February 2001; in Nuwara Eliya in June 2009; and in Ratnapura in November 2007. The number of diagnostic laboratory submissions by year and test location is given in Figure 3.2.

During 2009 the VRI received samples from 28 cases and the VICs received samples from 308 cases. Though the IDSAS enabled FVSs to report sample submission to a laboratory, the system did not allow individual samples from FVSs to be tracked to the VICs or VRI as indicated by the dashed lines in Figure 3.1.

Summary of the IDSAS data

The IDSAS operated for 365 days (January 1 2009 through to December 31 2009). During this period, 5758 unique surveys were submitted to the system by participating FVSs. This is equivalent to ~144 surveys/FVS over a 12-month period (12 per FVS per month). Of the total number of surveys, 4639 cases were reported, while the remaining 1119 surveys indicated no animal health issues. Of the unique surveys, 44.71% were received on the day they were completed while 78.08% were received within five days of completion. The survey required entries in all fields prior to completion. FVSs made a clinical diagnosis in 4402 cases, of which 247 (5.61%) had a gross post mortem examination performed. In 237 cases FVSs reported the cause of the case unknown, of which 18 (7.59%) had a gross post mortem examination performed (Figure 3.1). Of the 4639 cases submitted to the IDSAS, 326 (7.03%) reported contributing a sample to a laboratory (Figure 3.1).

Cattle herds visited by FVSs participating in the IDSAS averaged 6 animals in size, ranging from 1 to 150 animals. Buffalo herds averaged 23 animals and ranged in size from 1 to 198, while poultry flocks consisted of an average of 225 birds and ranged in size from 1 to 4500.

Applying the EID intelligence framework to the IDSAS and the diagnostic laboratory-based surveillance system in Sri Lanka

In Table 3.4 the performance of the IDSAS in Sri Lanka is summarized based on the proposed framework in Table 3.1.

<u>Early</u>

The IDSAS enabled regular and reliable collection of animal health-related data from FVSs. Though efforts were made to make summaries available in a timely fashion to stakeholders in the DAPH, data flow was unidirectional and data and summaries were not distributed to system users or stakeholders at other levels within the government veterinary services. Traceability was lost once a case left a FVS and was submitted to a diagnostic laboratory (cases in the IDSAS could not be linked to diagnostic laboratory submissions). There were people with the ability to interpret the data centrally and locally, but they lacked the means and ability to access the IDSAS data independently. Feedback was obtained from data providers, in particular about the structure and content of the survey, that could inform updates to the IDSAS.

Diagnostic laboratory data had to be manually reviewed and digitized in order to be made accessible. The majority of cases could be tracked down to the DS division level, and therefore matched to a FVS location, however there was no way of knowing if the case was submitted by a FVS and specific case location could not be determined. There were people with the ability to interpret the diagnostic laboratory data centrally and locally, but because the data were not available in a digital format neither easy nor routine access was possible.

Warning

The IDSAS was designed to ensure all fields for each record were complete. The system permitted enumeration of cases at various levels of the diagnostic hierarchy, including the total number of cases seen by FVSs, the number of cases where there was an animal health issue, as well as the number of cases for which a gross post mortem examination was done, and the number of cases sent to a diagnostic laboratory. As the IDSAS required submission of the number of animals on a farm and the number of animals affected for each and every animal health event, calculation of on-farm syndrome and disease rates was possible. Additionally, collection of animal census data permitted calculation of population rates. Table 3.5 provides an example of population and on-farm rates of the most commonly encountered syndrome by FVSs in cattle and poultry for two districts respectively. Though not included in this chapter, separate analyses of the IDSAS dataset have incorporated a variety of environmental data (C. Robertson, unpublished data).

There was no standardized data collection platform for diagnostic laboratory data: digitization required information to be pulled from laboratory reports with varying formats. The summary statistics illustrate data fields were frequently incomplete. The diagnostic laboratory data enumerated the number of cases submitted for diagnostic laboratory testing, the type(s) of tests performed, and the results of the tests performed. In addition there were some data available concerning characteristics of animals involved in cases. It did not permit calculation of population- or farm-level rates. Disease cases in animals separate from EID events were recorded. There were no means to incorporate environmental data into the data acquisition strategy.

Risk

The IDSAS enabled FVSs to make free-text entries in the event of making a clinical diagnosis. FVSs were not given other means of providing ancillary case information they felt was relevant. Local farmer information was not collected. However, the data collection platform could be modified to collect these types of data. The IDSAS had the ability to generate trend data about animal health issues that FVSs encounter in the field. Though no other such historical trend data exist in Sri Lanka (C. Robertson, Sawford, Daniel, Nelson, & Stephen, 2010), the DAPH compiles information from written monthly FVS reports and enters these data into the OIE World Animal Health Information Database. The DAPH is also exploring uses for the Transboundary Animal Disease Information System, a veterinary data management system. These data were not made available for analysis. Although the IDSAS had the ability to incorporate data from multiple sources, it was piloted using only FVSs as data providers. Various event detection algorithms were evaluated during the pilot phase, though complex baseline variations and a lack of baseline data made application of standard cluster detection techniques difficult. Work is ongoing to model the baseline variations in the IDSAS data (C. Robertson, unpub. data). DAPH stakeholders could pick out clinical diagnoses of interest from the weekly summary reports and follow up with FVSs if required (C.

Robertson et al., 2010). The IDSAS database was designed to collect and integrate agricultural and human census data, animal locations, and movements but data collection was restricted to animal health-related events in the pilot phase.

The diagnostic laboratory-based system did not collect or integrate local knowledge from data providers or farmers. Digitizing 10 years of select diagnostic laboratory data served to generate historical trend data, however there was no system in place in Sri Lanka for digitally storing and sharing diagnostic laboratory data from VICs or the VRI. As diagnostic laboratory data have traditionally been stored in paper format, they could not be analyzed in a timely and routine fashion for the purpose of event detection nor was integration with additional data sources possible.

Discussion

There remains much uncertainty as to how to operationalize an EID early warning system. In this chapter I propose and apply a framework for EID intelligence that includes key elements and specific system attributes against which existing surveillance systems can be compared. It was based on the premise that recent changes in the landscape of EID risks necessitate an approach that considers risk more broadly and places emphasis on the context in which animal health-related events take place, and within which animal-health related information is used by decision makers. Application of the framework was feasible and useful in illuminating the strengths and deficits of the IDSAS and current diagnostic laboratory-based surveillance infrastructure in Sri Lanka for EID early warning. The framework also allowed for the making of recommendations including steps that could be taken to strengthen the IDSAS –one such step would be merging the IDSAS with ongoing diagnostic laboratory-based surveillance (Table 3.4).

Few reports of animal health-related events are being received by diagnostic laboratory facilities in Sri Lanka, even with the addition of VICs. Given the diagnostic capacity in Sri Lanka and the small number of case submissions, the diagnostic laboratory system cannot serve solely as the basis for EID surveillance, and on its own, is unable to adequately identify and characterize the breadth of animal health-related events relevant to EID early warning. If the proposed EID intelligence framework is accepted as sufficiently supported by current literature, I demonstrate how the IDSAS could facilitate a shift from diagnostic laboratory-based surveillance to EID intelligence in Sri Lanka. The IDSAS could enable incorporation of timely frontline observations of animal health events and population risks into the existing diagnostic laboratory-based system.

Frontline mobile phone-based reporting has the potential to contribute to EID intelligence as shown by the IDSAS, which helped to describe the context in which animal health-related events occur. The IDSAS has the ability to increase greatly the number of case submissions and reports that are readily available to high-level officials. As the IDSAS is based on submissions from FVSs, it provides more opportunities to observe change within the animal population: FVSs visit farms, interact with farmers, and can gather ancillary data. FVSs are often the first to observe animal health-related events. In addition, as the IDSAS requires completion of all data fields prior to survey submission, the contextual information more accurately reflects the animal health situation as encountered by FVSs.

Utilization of the EID intelligence framework also revealed important weaknesses and deficits in the IDSAS pilot project. There was no way to link cases from the IDSAS to diagnostic laboratory case submissions. Information flow was entirely unidirectional. Stakeholders did not receive information in a timely enough fashion, nor were they able to access data independently of researchers. While the ability to incorporate and analyze additional information sources, including environmental data, relevant subsets of the agricultural and human census, and animal locations and movements, was inherent in the IDSAS, this capacity was never utilized within the pilot project.

The pilot stage of the IDSAS in Sri Lanka has come to a close and the IDSAS is no longer in operation. It was intended to serve as proof of concept and terminated in the form presented here when the research ended. Adaptation and integration with existing national disease surveillance in Sri Lanka is being explored. This highlights one of the challenges to surveillance –it takes considerable time and energy to develop and implement novel approaches. Current funding and project structuring do not allow for timelines sufficient to mount and maintain initiatives that meet the requirements of surveillance. The next steps in developing the IDSAS would have included facilitation of data access by stakeholders at all levels, incorporation of additional data sources, exploration and automation of statistical surveillance methods, incorporation of ongoing diagnostic laboratory-based surveillance into the IDSAS database, and transference of administration of the IDSAS to the DAPH.

Local knowledge from frontline health care workers in lower resource settings remains an untapped resource (S. Morse, 2007; Ndiaye, Quick, Sanda, & Niandou, 2003). Using existing technological capacity enables conversion of this knowledge into accessible and available data that can help achieve EID intelligence (Chretien et al., 2008). Future systems need to incorporate means of signal follow up that enable a response in advance of an etiological diagnosis and explore means of ongoing engagement of stakeholders (S. Morse, 2007). This approach will permit more rapid identification and response to animal health-related events which may, in turn, mitigate emerging risks to humans.

Table 3.1: Proposed Components of an Emerging Infectious Disease Intelligence System Supported by Published Evaluations and Criteria

System features	Elements	Goals	Components	Attributes for design and/or evaluation	Key references
Early	Timely awareness	To effectively communicate understandable information in a rapidly accessible manner to people with ability and authority in order that they interpret the information and act	A communications system that is regular, reliable, and multidirectional	Features of data acquisition and dissemination Traceability of individual cases through the system	Biermann et al., 2004; Chretien et al., 2008; C. Fraser et al., 2004; German et al., 2001; Lescano et al., 2008; Liao, 2001; Liao et al., 2003; Mandl et al., 2004; S. Morse, 2007; Paquet et al., 2006; Thurmond, 2003; Wagner et al., 2001; WHO, 2006a
			People with the ability to interpret the data centrally and locally	Ability and willingness of stakeholders to access and view data appropriately	Chretien et al., 2008; German et al., 2001; Lescano et al., 2008; Mandl et al., 2004; Stephen & Ribble, 2001; Wagner et al., 2001; WHO, 2006a
			An understandable and meaningful input format	Feedback from data providers regarding properties of the data collection platform	Biermann et al., 2004; Chretien et al., 2008; German et al., 2001; Lescano et al., 2008; Liao, 2001; Liao et al., 2003; Tataryn et al., 2007

System features	Elements	Goals	Components	Attributes for design and/or evaluation	Key references
Warning	Meaningful event information	To provide information to help forecast population-level prognosis	Data to fill the diagnostic hierarchy	Number of cases at various points in the system	Burkom et al., 2008; Christensen, 2001; German et al., 2001
			Data to define the magnitude of the problem	Ability to calculate population rates Ability to calculate farm-level rates	Christensen, 2001; German et al., 2001; Thurmond, 2003
			Contextual information on the problem of interest or unusual occurrence	Case characteristics accompany submissions	German et al., 2001; Lescano et al., 2008; Ribble & McLaws, 2007; Thurmond, 2003
		To provide peri-event information to help provide context	Concurrent health events	Ability to document other health-related events	Biermann et al, 2004; Burkom et al., 2008; Chretien et al., 2008; German et al., 2001; Lescano et al., 2008; Liao, 2001; Mandl et al., 2004; Stephen & Ribble, 2001
			Local environmental variability	Ability to incorporate environmental data	Burkom et al., 2008; Kaiser et al., 2006; Ka-Wai Hui, 2006; Paquet et al., 2006; Rabinowitz et al., 2005; Tataryn et al., 2007;

System features	Elements	Goals	Components	Attributes for design and/or evaluation	Key references
Risk	Unusualness	To recognize an event as unusual	Local knowledge	Ability to collect and integrate local knowledge from farmers and data providers	Ka-Wai Hui, 2006; S. Morse, 2007; Paquet et al., 2006; Ribble & McLaws, 2007; Stephen & Ribble, 2001; Tataryn et al., 2007
			Create/access historical trend development (species, disease, location)	Inventory of historical trend data or ability to generate trend data	Biermann et al., 2004; Burkom et al., 2008; Chretien et al., 2008; German et al., 2001; Halliday et al., 2007; Liao, 2001; Mandl et al., 2004; Tataryn et al., 2007; Wagner et al., 2001
			Analytical capacity	Ability to analyse data from multiple sources to detect an event and determine its significance	Biermann et al., 2004; Burkom et al., 2008; Chretien et al., 2008; German et al., 2001; Kaiser et al., 2006; Liao, 2001; Liao et al., 2003; Mandl et al., 2004; S. Morse, 2007; Paquet et al., 2006; Wagner et al., 2001
	Risk to the human population	To demonstrate the potential for human exposure	Document animal location and use with respect to the population of concern	Ability to collect and integrate agricultural and human census data, animal locations and movements	Christensen, 2001; Halliday et al., 2007; Kahn, 2006; Kaiser et al., 2006; Ka-Wai Hui, 2006; S. Morse, 2007; Paquet et al., 2006; Rabinowitz et al., 2005; Ribble & McLaws, 2007

Table 3.2: Veterinary Diagnostic Capabilities in Sri Lanka, 2009

Location	Diagnostic capabilities	Confirmable condition (if applicable)
Field offices	Clinical examination	
	Gross post mortem examination	
	California mastitis test (CMT)*	Mastitis
	Microscopy (+/- stain)*	Blood-borne parasites
VICs	CMT	Mastitis
	Microscopy (+ stain) and fecal flotation	Blood-borne parasites, intestinal parasites
	Aerobic bacterial culture	Bacterial infection
	Antibiotic sensitivity testing	Bacterial drug resistance
	Rose Bengal plate agglutination test	Brucellosis
	Rapid antigen detection	Highly pathogenic avian influenza
VRI	CMT	Mastitis
	Microscopy (+ stain) and fecal flotation	Blood-borne parasites, intestinal parasites
	Aerobic and anaerobic bacterial culture	Bacterial infection
	Antibiotic sensitivity testing	Bacterial drug resistance
	Histopathology	
	Complement fixation test	Brucellosis
	Milk ring test	Brucellosis
	Antigen detection enzyme-linked immunosorbent assay (ELISA)	Foot and mouth disease
	ELISA	Classical swine fever
	Reverse transcription-polymerase chain reaction (PCR)	Highly pathogenic avian influenza
	Pathogen isolation by egg inoculation	Newcastle disease
	Serology	Infectious Bursal Disease
		Infectious Bronchitis
		Reovirus infection
		Infectious laryngotrachitis

*Only select offices have these diagnostic capabilities.

Table 3.3: Measures of diagnostic laboratory data completeness in Sri Lanka, 2009

Field	Number of completed fields	Total number of cases	% of cases
Type of sample	1203	1208	99.6
Result of test	1193	1208	98.8
Type of test performed	1204	1208	99.7
Number of samples submitted	525	1208	43.5
Age	336	1208	27.8
Sex	134	1208	11.1
Number of animals in herd or flock	106	1208	8.8
Number of positive samples given a positive test result	264	859	30.7
Number of positive samples given a positive test result where the number of samples submitted was supplied	262	405	64.7

Table 3.4: Assessment of the Infectious Disease Surveillance and Analysis System as it contributes to emerging infectious disease intelligence in Sri Lanka

System features	Strengths	Limitations	Opportunities for development
Early	Timely Regular Reliable Acceptable Understandable Meaningful Interpretable Adaptable based on user and stakeholder feedback	Unidirectional No traceability Unsustainable Limited data dissemination Limited ability for stakeholders and users to access and view data	Incorporation of diagnostic laboratory data
Warning	Detailed information on individual cases Supplemented the diagnostic hierarchy Documented other health-related events	Disconnect between the level of the FVS and the diagnostic laboratories	Calculation of population- and farm-level rates Incorporation of environmental data
Risk	Provided case location data Inventoried historical trends on syndromes and endemic disease Collected and integrated local knowledge from FVSs	Limited local analytic capacity Limited ability to collect and integrate local knowledge from farmers	Collection and integration of agricultural and human census data, animal locations and movements Analysis of data from multiple sources

Table 3.5: Case counts, population and on-farm rates for selected syndromes and districts

Syndrome and Species	**Nuwara Eliya**			**Matara**		
	Cases	Population case rate	Farm-level case rate	Cases	Population case rate	Farm-level case rate
Cattle: Decreased feed intake/milk production	853	853/29823[1] 2.860%	853/3217[2] 26.515%	317	317/9286[1] 3.413%	317/1316[2] 24.088%
Poultry: Decreased egg production/ weight gain/appetite	121	121/151676[1] 0.07978%	121/1239[2] 9.766%	14139	14139/100722[1] 14.038%	14139/30069[2] 47.022%

[1]Denominators derived from the 2008 Census of Agriculture
[2]Denominators derived from the IDSAS database

Figure 3.1: Structure and flow of data concerning animal health-related events in Sri Lanka from 1 Jan 2009 to 31 Dec 2009, in addition to the IDSAS as it relates to existing disease surveillance activities. Green-filled shapes represent hierarchical levels within the government veterinary services of Sri Lanka. Green-filled circles represent sources from which data was collected. Arrows represent the flow of information: blue arrows representing case flow through the IDSAS; grey arrows indicate known flows of data which could not be quantified; dashed arrows represent loss of traceability of data. The numbers quantify case counts at various levels in the diagnostic hierarchy. (RA – Research Assistant, LDO – Livestock Development Officer, FVS – Field Veterinary Surgeon, VICs – Veterinary Investigation Centres, VRI – Veterinary Research Institute, DAPH – Department of Animal Production and Health)

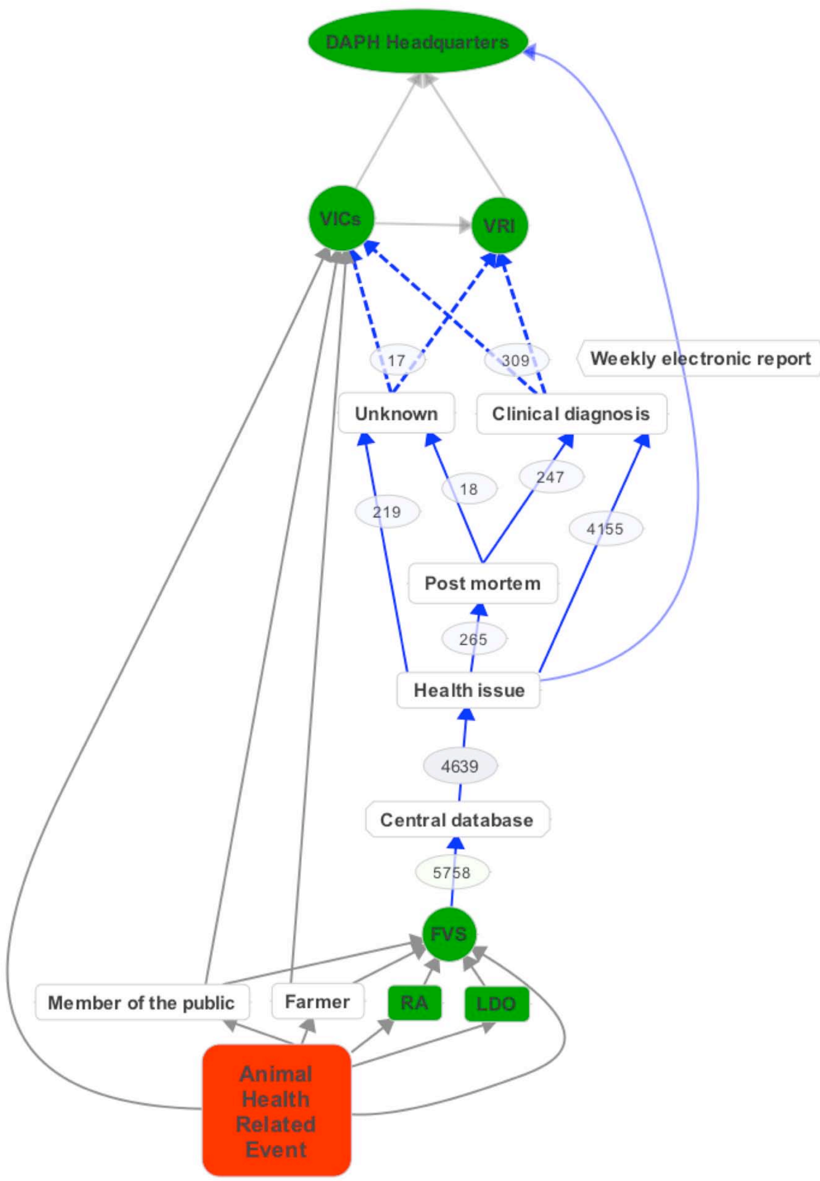
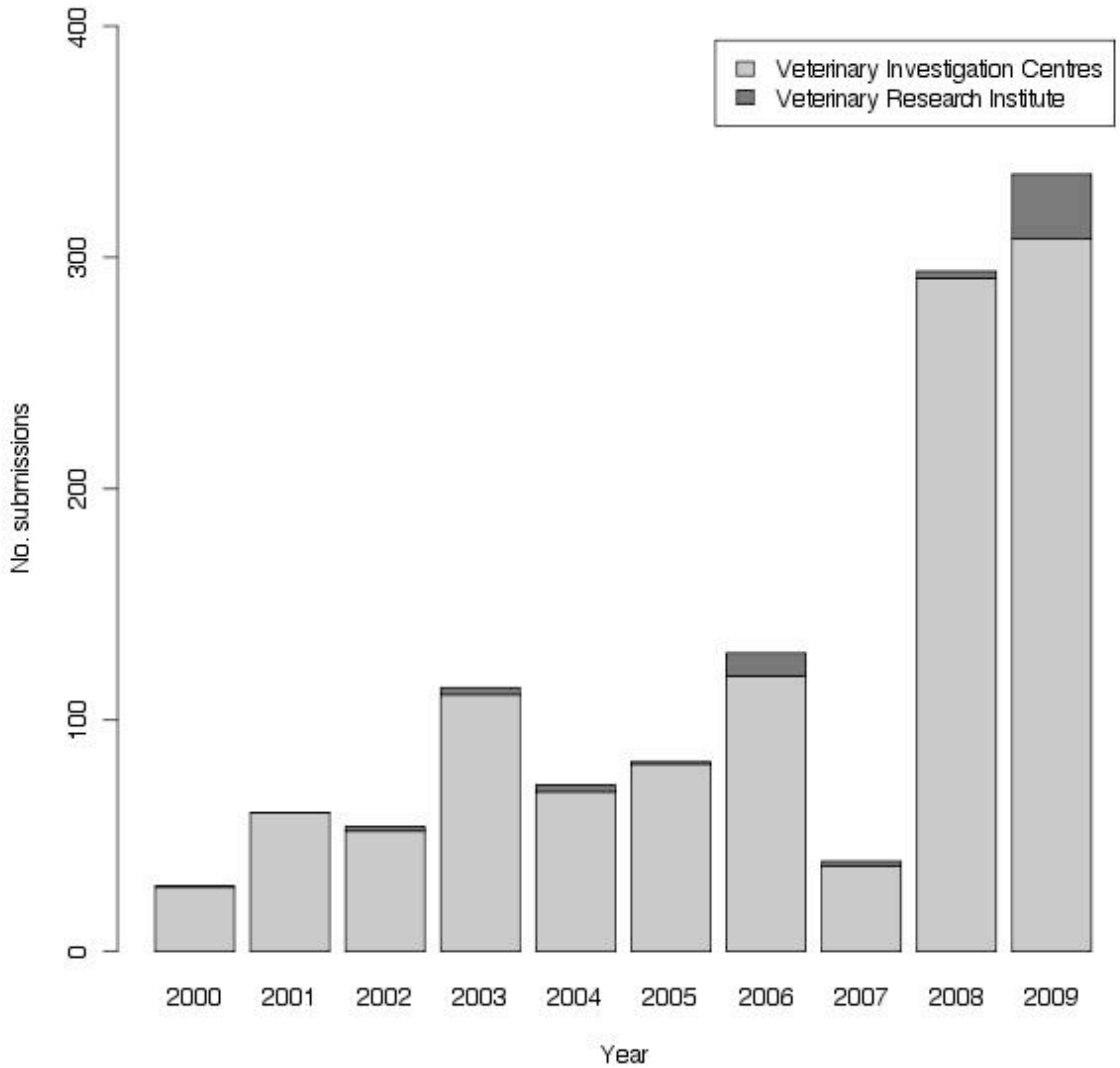


Figure 3.2: The number of diagnostic laboratory submissions by year and testing facility



CHAPTER 4: SRI LANKAN VETERINARIANS' DECISION MAKING ABOUT DIAGNOSTIC LABORATORY SUBMISSIONS AND PERCEPTIONS OF DISEASE SURVEILLANCE

Introduction

Surveillance is a rapidly changing practice, in part due to the challenge posed by EIDs (Wagner et al., 2006). Surveillance of animal populations is critical as they have been the source of many EIDs with direct human, animal and environmental health consequences, including highly pathogenic H5N1 and H1N1 influenza viruses, severe acute respiratory syndrome (SARS), Ebola virus, and Nipah virus (Daszak, 2009; Rouquet et al., 2005; Wagner et al., 2006). Preventing and containing the socio-ecological impacts of EIDs requires early detection and response to EIDs in animals before there is wide-spread disease in the human population (WHO, 2006b).

Animal health surveillance has historically targeted submissions to diagnostic laboratories, much like in human health, where the aim is to make an etiological diagnosis (Hueston, 1993). Surveillance of submissions to diagnostic laboratories will continue to be an important component of any infectious disease surveillance system because for many infectious diseases laboratory tests are the only way to make an etiologic diagnosis. In addition, etiological diagnoses can inform control and policy responses. However, in the case of EIDs, diagnostic tests may not exist for novel or previously unknown pathogens, making surveillance reliant on other data. Moreover, not all potential cases of infectious disease are submitted to diagnostic laboratories. In the domestic animal health field there is a series of selection biases that affect which cases are submitted for etiological testing. Veterinarians are often the primary decision-makers in the process that determines which cases will be submitted for diagnostic laboratory testing. The decisions made by veterinarians influence the types and amounts of samples that are assessed at the level of the diagnostic laboratory, introducing potential sampling biases that will affect disease patterns described by laboratory-based surveillance (M. C. Thurmond, Blanchard, & M. Anderson, 1994). In order to understand this selection bias in diagnostic laboratory-based surveillance, submission patterns of veterinarians and the factors that influence their decision to submit samples must be better understood (M. C. Thurmond et al., 1994; Watson, David, & Cook, 2008; Zurbrigg, 2009).

Surveillance methodologies that utilize pre-diagnostic data generally have the aim of identifying disease outbreaks earlier than would have been possible with more traditional diagnostic laboratory-based surveillance methodologies (Bravata et al., 2004, e.g., Doroshenko et al., 2005; R. Heffernan et al., 2004; Josseran et al., 2006; Lemay, 2008; Lewis et al., 2002; Smith et al., 2006). Focus is diverted away from etiological or definitive diagnoses and onto patterns in clinical signs or syndromes. The initial step in realizing the potential of these methods in high-resource settings is securing access to appropriate data (Bravata et al., 2004; Dorea et al., 2011b). In low-resource settings, where digital storage of information is limited, the initial step is often to engage various subsections of the health care community to provide necessary data (L. May et al., 2009). In many settings it is primarily veterinarians who provide healthcare services to domestic animals, in partnership with farmers. Veterinarians have access to animals and are frontline observers of signs of disease, making them an ideal source of pre-diagnostic data from the animal population. A number of animal disease surveillance programs rely on veterinarians to provide data (Del Rocio Amezcua, Pearl, Friendship, & McNab, 2010; Government of Alberta, Agriculture and Rural Development, 2010; Lemon et al., 2007; McIntyre et al., 2003; C. Robertson et al., 2010; Van Metre et al., 2009). Understanding veterinary attitudes toward surveillance is therefore foundational to the development and assessment of pre-diagnostic surveillance systems that use animal data to forecast risks to humans.

Qualitative research methods are being increasingly utilized in low-resource settings to identify factors that impact the uptake and application of health-related ideas, technologies, and practices (Arvelo et al., 2011; Singer et al., 2007; Weigel & Armijos, 2001; Wong, 2010; Wong, 2011). They have also been employed in the human health field to explore the use of health data in public health practice, as well as factors that act to facilitate or hinder use of these data (Bloom et al., 2000; Pope & Counahan, 2005; Wilkinson et al., 2007). However, no published peer-reviewed qualitative research papers could be identified in the literature on the subject of utilization of diagnostic laboratory services by frontline animal health care workers in low-resource countries. This lack of information precludes confident assessment of the representativeness of animal infectious disease occurrence data in many low-resource countries where reporting is based on laboratory submissions from frontline animal healthcare workers. There are also no published peer-reviewed research papers available on the subject of the ability and willingness of frontline animal health care workers in low-resource countries to participate in pre-diagnostic case reporting initiatives. This represents a significant deficit in the literature given the call for further development of pre-diagnostic surveillance initiatives in low-resource countries (Chretien et al., 2008).

In this chapter I report the results from a focused ethnographic study that aimed to advance understanding of the factors that influence government field veterinarians in Sri Lanka to submit cases to a diagnostic laboratory, and to describe their perceptions of infectious disease surveillance, including the complex of factors that impact their ability and willingness to participate in surveillance programs. The results reported here can inform interpretation of infectious disease patterns reported by veterinary diagnostic laboratory-based infectious disease surveillance systems in low-resource settings and improve efforts to engage frontline animal health care workers in future surveillance initiatives.

Materials and Methods

Study design

In focused ethnography, research is not directed towards a culture but rather a particular subculture or group of participants that share some feature or features (J. Morse & Richards, 2002). The term focused ethnography describes a research approach employed when what is sought is an explication of behaviour or beliefs pertaining to a specific area so that their meaning among a defined group of individuals might be understood (J. Morse & Richards, 2002). This method is employed when research questions are best responded to through descriptive analysis and interpretation (J. Morse & Richards, 2002).

This study is composed of in-depth interviews with participants linked by their experience as FVSs employed by the DAPH, a national-level body responsible for control of livestock diseases, livestock research, animal breeding, and education in animal husbandry in Sri Lanka, who also participated in the IDSAS. The IDSAS is a mobile phone-based surveillance system that was piloted in Sri Lanka in partnership with the DAPH during 2009. It enabled FVSs to submit data concerning animal health-related events from the field on a daily basis (refer to Chapter 2).

For the purpose of this study, veterinary disease surveillance is defined as continuous efforts to collect, collate, and interpret information about the health and disease status of a defined animal population, wherein information is disseminated to those responsible for public health actions taken in response to changes in the animal population deemed significant (Doherr & Audige, 2001; Höhle, Paul, & Held, 2009). A brief description of the diagnostic laboratory capacity available to FVSs in Sri Lanka provides contextual information necessary for interpreting data collected during the interview process. Context is defined as the circumstances, including personal, community, economic, political, social, cultural, epidemiologic, and regulatory, in which disease surveillance is being performed (Fetzer, 2004). In-depth interviews were conducted in January 2010. The Conjoint Health Research Ethics Board at the University of Calgary approved the study proposal (Ethics ID number 5136).

Study participants

Eligible participants included FVSs in Sri Lanka that took part in the IDSAS (refer to the methods section of Chapter 2 for details on how IDSAS locations and participants were selected). The author (KES) initially approached participants at the onset of the IDSAS pilot project. She gave them a brief description of the research aims and format and asked if they would be willing to participate. Potential participants were told that KES is a veterinarian who continues to work in clinical practice while enrolled in a graduate program. This explanation was intended to facilitate access to information by conveying that KES had some prior understanding of the challenges faced by veterinarians providing clinical services to the domestic animal population. All forty FVSs who took part in the IDSAS consented to the in-depth interview process. Eligible FVSs were characterized by age, year of graduation from veterinary school, years as a FVS, sex, DS division, and district practice location. During January 2010, twelve of the forty FVS volunteers were purposively selected to participate in the in-depth interview process with the aim to construct a group of participants with maximum demographic variation in the characteristics listed previously. In studies that ask questions similar to the ones posed in this study, six in-depth interviews usually allows for data saturation, while when twelve in-depth interviews are performed data saturation is almost always attained (Guest, Bunce, & Johnson, 2006). Data saturation is defined as the completion point of the data set and results when there is data replication or redundancy (Bowen, 2008). It has occurred in qualitative research when there are no new information or themes emerging from subsequent interviews and the categories, themes and relationships between them are thoroughly described (Bowen, 2008). The goal of maximum variation sampling, a form of purposive sampling, is to gain a breadth of knowledge of the context in which participants act (Sandelowski, 1995). KES and the research assistant sat down together to select the twelve participants based on the desired characteristics of the final sample, namely: three individuals from each of the four districts participating in the IDSAS; an approximately balanced sex ratio; a wide range in age, years in practice, and years as a FVS; and a high degree of proficiency in spoken English and English language comprehension as an attribute common to all participants. The research assistant who helped to set up and maintain the IDSAS identified individuals with above average English language abilities: all FVSs spoke English as all attended veterinary school in English, however there was variation in English proficiency between potential participants. Descriptive statistics were used to summarize the characteristics of the study participants.

In-depth interview structure

The twelve selected participants were contacted individually to schedule times for interviews. Because of the lengthy travel time between districts, all three selected FVS participants in each district were interviewed separately during a single visit. In-depth interviews were conducted at the location of choice of the participant. Most often this was at the clinic of the FVS. Participants were asked at the beginning of the interview to confirm orally that they had signed the informed consent. Each in-depth interview, conducted in person by KES, was no longer than 2 hours in length. A semi-structured format with a series of standardized open-ended questions was used (Table 4.1). An initial set of follow-up probes was drafted and employed where appropriate: probes evolved as subsequent interviews were conducted (Table 4.1).

All in-depth interviews were recorded using two digital audio recorders. At the end of each interview the recordings were downloaded onto a password-protected laptop computer. Both audio files were reviewed to ensure the interview had been recorded in its entirety. There was only one month available to conduct all of the interviews and therefore analysis of the audio files was not possible between interviews. Audio files were reviewed between each set of interviews in the four districts to inform probes used in subsequent interviews and to allow interviews early in the research process to inform those that came later. Interview data collection ceased after completion of the twelfth interview. Interviews were transcribed verbatim from the audio recordings by a professional transcriptionist at the end of the interview data collection period. Personal identifiers were removed from the transcribed files to ensure participants' responses remained anonymous. A single copy of each original audio file was transferred onto two password-protected DVDs, which were stored together in a locked cabinet in a locked office according to University of Calgary policy. All original audio files were then removed from the laptop computer. Data were analyzed after transcription of the interview audio files.

Collection of interview data concluded after the twelfth interview due to time constraints. KES was only in Sri Lanka for a limited time period and it was not possible to conduct further interviews or analyse the data prior to departure. Other reasons for terminating data collection include: data saturation has been achieved; a lack of available individuals who meet the study inclusion criteria; and budgetary constraints (Strauss & Corbin, 1998). The travel time between districts, the limited time available for interview data collection, and the desire to achieve data saturation were the drivers behind the sample size of twelve.

There were a number of data sources accumulated in addition to the in-depth interview transcripts: memos were made by KES to document decisions made in the data collection and analysis process, day-to-day activities, and any comments concerning methodology; a reflective journal was kept by KES, further describing the research process and the researcher's experience with participants; and fieldnotes were used to record any observational data. Memos and the reflective journal were captured directly in Microsoft Word while fieldnotes were hand-written onto the interview guide during each interview and later transcribed. All raw data and material arising from the research activity were scanned into electronic files and the original documents destroyed. The electronic version of these materials is being stored by Dr. Craig Stephen, Principal Investigator and Doctoral Supervisor, for seven years as required by the University of Calgary's Faculty of Medicine Research Policy Guidelines for Integrity in Scholarly Activity.

Data analysis

The first step in the analysis of the transcripts from the in-depth interview audio recordings involved reading through all of the transcripts and coding the data by interview question using NVivo 9 (N9), a qualitative analysis software suite that enables researchers to organize and retrieve qualitative data, including textual material, to get a sense of the data set as a whole. Thematic analysis (Graneheim & Lundman, 2004) was then performed on the transcripts. During the process of thematic analysis, data were systematically organized within N9 using codes that KES inductively derived from the records. The goal was to identify concepts, categories, relationships, and themes. Concepts are the basic units of analysis. During identification of concepts, the central meaning of each piece of transcribed text was described in a short statement, referred to as a code (Graneheim & Lundman, 2004). Concepts were grouped in categories, groups of content that share common features. Similarly, categories were organized around themes. Creating themes is a way of linking underlying meanings that reoccur within categories (Graneheim & Lundman, 2004). Individual categories and themes were described by a code (Graneheim & Lundman, 2004). All of the codes were reviewed to ensure the concepts, categories, themes, and relationships between them were completely and appropriately described. All data presented in the results section reflect the observations, insights, and opinions expressed by participants. Following analysis of the twelve interviews it was determined that data saturation had been achieved.

In the interviews the meaning of the conversation was more evident than the original transcripts suggest, because of accompanying facial expressions and gestures (Streeck, 1996). In order to convey the information in clear language, the participants' wording within quotes included in this chapter has been edited. This editing was done carefully to make quotes easier to grasp while preserving the meaning conveyed in the original text. This approach is respectful because participants are educated people that would be more articulate if they were speaking in their first language. Editing is being employed in this instance to allow participants' accounts to flow smoothly. This approach is deemed necessary and appropriate in qualitative research when participants speak English as a second or third language (Boeije, 2010; R. S. Weiss, 1994).

Trustworthiness is pursued as part of qualitative research studies. The aim is to demonstrate that the findings are 'worth paying attention to' (Lincoln & Guba, 1985; Shento, 2004). In order to establish trustworthiness of the findings presented in qualitative research studies four criteria have been proposed: (i) credibility (preferred over internal validity, a criteria employed by quantitative investigators) (ii) transferability (comparable to external validity/generalisability, a criteria employed by quantitative investigators); (iii) dependability (comparable to reliability); and (iv) confirmability (comparable to objectivity) (Shento, 2004).

(i) Credibility

Credibility is concerned with the extent to which the findings reflect reality (Shento, 2004). Shento (2004) lists a number of procedures that can inform design of a qualitative research study to promote confidence in its credibility. A number of these measures were incorporated into this study: focused ethnography and thematic analysis are well-established approaches in the qualitative research field; KES was exposed to the circumstances under which FVSs practiced veterinary medicine and interacted with participants prior to data collection to gain an understanding of the government veterinary services in Sri Lanka and build a relationship of trust with participants; maximum demographic variation sampling was employed as a means of triangulation via data sources so that the data reflect the attitudes, opinions, practices, and experiences of a range of individuals; participants were given the opportunity to refuse to participate and could withdraw from the interview at any time as a means of ensuring honesty among participants; participants were probed about specific previous diagnostic laboratory submissions in order to ensure contradictory data were not being supplied; KES frequently debriefed with Dr. Craig Stephen and Dr. Ardene Vollman, a qualitative methodologist and supervisory committee member, to discuss ideas and interpretations related to the findings, and to review the research process; the research project was discussed with peers to give KES the opportunity to receive feedback from individuals in the field but outside of the research project; reflexivity, or the "active acknowledgement by the researcher that her/his own actions and decisions will inevitably impact upon the meaning and context of the experience under investigation" (Lietz, Langer, & Furman, 2006), was a constant component of the research process of KES and ensured the project was being evaluated during all phases of the research; KES received training in qualitative methods prior to design of the research project and data collection to ensure KES had the qualifications and skills necessary for project execution; and KES reviewed the literature to determine the extent to which the findings from this research project were consistent with previous investigations in the fields of health, surveillance, and qualitative methods to demonstrate how the findings fit with the existing body of knowledge (Shento, 2004). While member checking, in which the findings of the research are shared with participants to give them the opportunity to comment on the findings, is advised as a means of ensuring credibility (Shento, 2004) it was not carried out as a part of this project due to geographical barriers.

(ii) Transferability

Transferability is defined as the ability to apply findings from a qualitative research study to other situations (Shento, 2004). Qualitative research involves small numbers of participants at a particular time in a specified environment, and therefore it is impossible to demonstrate the transferability of findings and conclusions to other contexts or populations (Shento, 2004). It is the responsibility of the reviewer of the research to consider the context in which the research was conducted and decide whether or not findings and conclusions can confidently be transferred to other situations (Shento, 2004). Therefore it is critical that qualitative researchers provide a detailed description of the boundaries of the study including: the number of participants and their locations; inclusion and exclusion criteria for participants; the data collection methods; the number and length of data collection sessions; and the time period over which data collection took place (Shento, 2004). All of this information is provided as part of this chapter.

(iii) Dependability

Many quantitative researchers strive to demonstrate that, were their study repeated using the same methods under the same conditions, the findings would be similar (Shento, 2004). Qualitative research targets individuals and groups of individuals that by definition change over time: data and results are inseparable from the time period and situation under which they were collected (Shento, 2004). Therefore, dependability in qualitative research comes down to provision of sufficient detail so that the study could be repeated in future, though not necessarily to achieve the same results (Shento, 2004).

The details provided in this chapter would enable a future researcher to perform this study again.

(iv) Confirmability

In qualitative research, the researcher is the instrument of data collection, which by definition introduces researcher bias into the research process. This negates the ability of the researcher to ensure objectivity. Qualitative research then is concerned with confirmability, or the extent to which the findings are a reflection of the experience and ideas of participants, as opposed to those of the researcher (Shento, 2004). To ensure confirmability in this study: triangulation via data sources was employed; an audit trail was maintained that documents the research process; bracketing, or the suspension of beliefs around particular phenomena, was part of data collection and analysis by KES and ensured there was ongoing questioning of the findings; and reflexivity was a critical component of the research process (Shento, 2004).

Results

Veterinary diagnostic laboratory infrastructure in Sri Lanka

The DAPH carries out surveillance for OIE listed diseases and EIDs in animals. The VRI operates under the DAPH and is the only national-level organization in Sri Lanka that provides veterinary laboratory diagnostic services. District-level laboratory diagnostics are provided by VICs located in the following districts: Anuradhapura, Badulla, Hambanthota, Chillaw, Jaffna, Matara, Peradeniya, Rannala, Polonnaruwa, Ratnapura, Vaunia, Welisara, Kegalla, Nuwara Eliya, and Dambulla. This represents a subset of the twenty-five districts in Sri Lanka. Each VIC is headed by a Veterinary Investigation Officer (VIO), a senior veterinarian with experience working as a FVS. One aim of the DAPH is to establish VICs in every district in Sri Lanka. All participants worked in districts in which there was a VIC.

Study participants

Each of the twelve participating FVSs practiced veterinary medicine in a distinct DS division. Three came from the Matara district; three from the Anuradhapura district; three from the Nuwara Eliya district; and three from the Ratnapura district. For a map of the study districts refer to Chapter 2, Figure 2.1. Participants ranged in age from 33 to 54 years (median, 37 years; mean, 39.5 years); 7 were male (58%). Participants graduated from the Faculty of Veterinary Medicine and Animal Science at the University of Peradeniya between 1984 and 2003 (median, 1999; mean, 1997). Participants had from 2 to 24 years (median, 5.5 years; mean, 7.96 years) of experience as a FVS within the DAPH. Further details about the study participants are not provided to protect their identities.

Overview of the themes and categories

Analysis of the data collected during discussions pertaining to decision making around diagnostic laboratory submissions revealed three themes. The first was concerned with FVSs and their interactions with diagnostic laboratories. Grouped around this theme were six categories: the reported frequency of submissions to diagnostic laboratories; cases from which samples were submitted; the tools employed in making a diagnosis;

perceived benefits of diagnostic laboratory assistance; desire for further diagnostic laboratory capacity; and future diagnostic laboratory submissions.

The second theme was factors underlying the frequency of case submissions to diagnostic laboratories. Categories associated with this theme were: farmer-level factors; FVS-level factors; and factors related to infrastructure and veterinary services in Sri Lanka.

FVSs and surveillance was the third theme in the data. Analysis revealed four categories that clustered around this theme and describe the complex of factors that affect the ability and willingness of FVSs to participate in EID surveillance programs: perceptions of the role and value of surveillance; perceived limitations of current surveillance methodologies; willingness to participate in surveillance initiatives; and challenges to surveillance methodologies that rely upon FVSs to submit pre-diagnostic data. The themes and categories are summarized in Table 4.2 and related to the core research aims of this study.

Theme one: Field veterinary surgeons' interactions with diagnostic laboratories

When asked the question 'describe the various factors that affect your decision to submit samples for laboratory diagnostics', participants did not supply the information requested. As an example, when asked about what affects their decision to collect samples and send them to a laboratory, one participant said:

> The thing is there were no lab facilities available earlier and now the situation has changed. Bacterial culture and antibiotic sensitivity testing as well as basic blood tests are

> done at the VIC but still, for pathology and some chemical analysis because the facility is not there, in making a diagnosis it will be best to rely upon the clinical signs and the animal's recovery after therapy. (Interview 2, Lines 10-15)

In trying to answer this question, participants focused not on the decision to submit samples or not but rather on how participants interacted with the diagnostic laboratory system in Sri Lanka. There were six categories identified that relate to FVSs' interactions with diagnostic laboratories: 1) the reported frequency of submissions to diagnostic laboratories; 2) cases from which samples were submitted; 3) the tools employed in making a diagnosis; 4) perceived benefits of diagnostic laboratory assistance; 5) desire for further diagnostic laboratory capacity; and 6) future diagnostic laboratory submissions (Table 4.2).

The reported frequency of submissions to diagnostic laboratories

When participants were probed specifically about the frequency of diagnostic laboratory submissions over the previous year, responses typically ranged from one sample per year to one sample per month, though some said they could not specify a number of samples. Though a few participants referred to sending samples to the VRI in general terms, only one cited a case where samples were sent to the VRI for the purpose of vaccine preparation. Some participants stated specifically that they had never sent samples to the VRI. When participants talked about specific cases, they often referenced VICs as the diagnostic laboratory to which they submitted samples.

Cases from which samples were submitted

Participants discussed types of cases from which they submitted samples. Two participants indicated that they send samples for diseases that spread or diseases that are highly contagious, while two participants indicated that they sometimes send a sample to a diagnostic laboratory when the initially prescribed treatment proves ineffective. One participant discussed sending samples from three to five cases annually to gain knowledge. Another referred to two specific cases where a notifiable disease was suspected from which samples were submitted. Participants reported that they employed means other than diagnostic laboratories to make a diagnosis.

The tools employed in making a diagnosis

Participants employ means other than diagnostic laboratories, including the history, clinical signs and physical exam findings, to guide their approach to cases and arrive at a diagnosis. A few participants described in general terms using the history, clinical signs, and physical exam findings to guide their approach to cases, while others stated explicitly that the history, clinical signs, and physical exam findings were important to making a clinical diagnosis. One participant cited a specific example where the history, clinical signs, and physical exam findings enabled a clinical diagnosis. According to two participants, obtaining a history can sometimes be frustrating.

> Farmers don’t keep records. Big farms keep records but only one big farm keeps proper records. The others don’t do it properly, and 95 percent of farmers do no recording at all. In order to diagnose a drop in egg production we need to consult records. Without records we can’t diagnose a decrease in egg production. (Interview 10, Lines 435-443)

A few participants provided an example of a list of differential diagnoses for particular case presentations. Participants talked consistently, in both general terms and using specific case examples, about basing their diagnoses and treatment choices on the clinical signs they observe. For example, when asked about the value of diagnostic laboratory tests in cases when they are submitted, one participant declined to answer the question and instead responded:

> Okay, now I am diagnosing only by the clinical signs. The diagnosis depends on the clinical signs and my judgment. I'm very experienced. If I haven't seen a particular situation or case before I will be administering treatment blindly because I don't know the blood chemistry or something like that. (Interview 2, Lines 123-128)

A few participants stated explicitly that previous experience informed their ability to make diagnoses and treatment decisions based on clinical signs. As a participant explained:

> Through experience we got trained to do the diagnosis on our own, we got self trained, got trained and trained to get the diagnosis on our own. (Interview 6, Lines 18-29)

One participant explained that for most cases in their clinic a farmer is supplied with medications to administer himself based on the reported clinical signs, rendering it unnecessary for the FVS to travel to the farm to perform a clinical exam. In such instances veterinarians rely on the history and clinical signs as reported by the farmer to make a diagnosis.

Some participants had no diagnostic laboratory tests available in their clinic, while others indicated they were able to run the CMT in their clinic or in the field. Microscopes were available in some clinics for veterinarians to examine blood smears, however, only one participant could stain blood smears. A couple of participants have utilized laboratories outside of Sri Lanka’s government veterinary diagnostic services, including a human laboratory and nearby college.

Participants consistently referenced gross post mortem examination as part of their diagnostic process, particularly for poultry: many times references to gross post mortem examination named poultry as the species involved and several participants stated explicitly that gross post mortem examination was important for making a diagnosis in poultry. A few participants indicated they had performed gross post mortem examinations on cattle.

The importance of the response of the animal to therapy was stressed by several participants: it was discussed as part of making a clinical diagnosis and guided their approach to future cases.

> I think that if my diagnosis is correct and my treatment is correct the animal will recover. There may be cases where my diagnosis is wrong but the treatment is correct and that is what is important. I will be okay with that, I think the diagnosis will be okay. (Interview 2, Lines 381-387)

Two participants indicated that they follow up with the farmer one or two days after administering treatment to find out if the animal’s condition has improved, while two others indicated that if an animal does not respond to an antibiotic they switch to a different antibiotic.

Many participants referred to professional sources of assistance as part of their diagnostic process. A number stated that they referred cases to the VIC or VIO and a few indicated that the VIO had come to help them with a challenging farm or case. One participant had called the VIO for advice but reported sending very few samples to the VIC because it is too far away. Another participant opted to call faculty veterinarians at the University of Peradeniya about difficult cases and described sharing successful case outcomes with colleagues at meetings. The assistance of public health inspectors and the police was reported in an instance when the head of an animal needed to be submitted for rabies testing. Being part of an emergency response team with the ability to contact other members quickly in the case of an infectious disease event was important, said one participant:

> I think that it is very good to participate in this program [the emergency response team] because we create a good communication system with other offices and head offices so that if there is a really pathogenic disease we can immediately contact one another. (Interview 7, Lines 329-333)

<u>Perceived benefits of diagnostic laboratory assistance</u>

Several participants indicated that laboratory diagnostics are valuable in that they can identify the agent, confirm the clinical diagnosis, and inform treatment. Some participants talked about the kinds of cases assisted by diagnostic laboratories: antibiotic sensitivity testing in cases of mastitis; yogurt and curd cultures for confirming *E. coli*; vaccine preparation in cases of warts; bacterial culture for confirming a salmonella outbreak; and testing in cases of a suspected viral or bacterial etiology.

Desire for further diagnostic laboratory capacity

On the subject of additional diagnostic laboratory capacity some participants talked about the types of diagnostic tests they would like to run, while others talked more about the types of diseases for which they would like to test. One participant talked specifically about the desire to be able to measure [parasite] eggs per gram of feces; create, stain, and examine microscope slides; quantify leukocytes; and measure packed cell volume in the clinic. All participants indicated they would like the ability to perform further diagnostics, though there were differences among participants about which specific tests they would like to do. Named diagnostics and targeted case presentations included: mastitis; bacterial culture and antibiotic sensitivity testing; brucellosis testing; cases for which there is no clinical diagnosis; testing for parasitic disease; blood calcium measurement; leukocyte counts; blood testing generally; cases in poultry; infectious disease cases; unusual cases; and cases where there is sudden morbidity and mortality, particularly in poultry. A couple of participants indicated they would like to send more cases to the diagnostic laboratory but did not specify the types of cases they would like to submit or testing they would pursue.

Future diagnostic laboratory submissions

Participants discussed future circumstances under which they intended to submit samples. A number of participants indicated that they will submit cases when they suspect a notifiable disease: the diseases specifically mentioned were black quarter (*Clostridium chauvoei*), foot and mouth disease (FMD), and brucellosis (*Brucella abortus)*. Some participants indicated that they would send either farmers themselves or samples to the diagnostic laboratory in cases of high mortality in poultry. One participant indicated that samples would be sent in cases where both chicken and cattle had the same clinical signs.

Theme two: Factors underlying the frequency of case submissions to diagnostic laboratories

Factors that provide explanation for the frequency of case submissions to diagnostic laboratory were categorized as occurring at one of three levels: 1) the farmer; 2) the FVS; and 3) related to veterinary services and infrastructure (Table 4.2).

Farmer-level factors

There are factors that explain the limited number of case submissions to diagnostic laboratories that operate at the level of the farmer: 1) notification of a FVS of an animal health-related event; 2) delivery of samples to a diagnostic laboratory; 3) level of education; and 4) farmers' sources of income and economic status.

1) Several participants talked about farmers notifying them when they have a concern, and a few indicated that they believe farmers always contact them when they have a concern or when an animal is sick. However, one participant indicated that farmers are not always concerned about a death:

> They [the farmers] don't bother about a dead chick. If there are ten hens and one dies they will not bother about it. If it increases to four or five affected the hens show clinical signs. If only one hen shows signs they will come with one

> hen and I will treat only the one hen. (Interview 2, Lines 268-277)

In the case of deaths in a poultry flock, farmers bring birds for gross post mortem examination to the FVS, giving the FVS an opportunity to examine the dead birds and submit samples to a diagnostic laboratory. However, in the case of deaths in large animals farmers often bury carcasses and do not inform a FVS when an animal has died. Even when a farmer informs the FVS of an animal death, the cause of death can remain unknown: a few participants cited specific cases of death where the cause was never identified. One participant described the following instance:

> We have had one or two cases of generalized edema in cattle. The animal gets bigger and bigger by the day and within two to three days they die. Everything, the head as well as the legs, is edematous. Still we are not sure what they are dying of. (Interview 4, Lines 246-253)

One participant mentioned that more experienced poultry farmers decline to bring dead birds to the clinic because the pharmacy will provide the farmers with pharmaceuticals without a prescription.

2) Several participants talked about the reluctance of farmers to deliver samples to the diagnostic laboratories. In some cases participants reported collecting samples but the farmer did not deliver them to the diagnostic laboratory, or simply declined to deliver samples collected.

> If we need to send a sample sometimes the farmer says yes, I will take the sample but they don’t do it. I know that last time there was a salmonella outbreak most samples were not delivered to the VIC. I know this because I wrote down all the cases of salmonella, including the name of the farmer, the species, and the tentative diagnosis, what I did,

> and then I sent it to the VIC. Last month I got a record from the VIC of how many farmers delivered the samples. The VIC received samples from only seven farmers. (Interview 10, Lines 182-192)

Another participant described the following circumstance:

> In the last month I've recorded two or three cases of rabies in large animals. However, the farmers did not bring the heads to {town name}. It is a large head, no? They don't like to cut and bring the head but based on the clinical signs we decided it was rabies. (Interview 12, Lines 333-340)

Dairy farmers in particular have limited ability to leave the farm. One participant indicated that they will transport samples to the diagnostic laboratory if the farmer is unable to do so and another stated that staff from the diagnostic laboratory will collect samples or veterinary office staff will transport samples.

3) The initial education level of farmers presented a challenge to some participants, with reference to language barriers and illiteracy in particular.

> Some farmers are coming and saying that the cow is not chewing the beetles but we know from experience that they mean the cow is not eating and not regurgitating and that there is some problem. (Interview 2, Lines 617-624)

In some instances, a farmer's perception of a serious condition was reported to differ from that of the FVS or animal.

4) Farmers do other work beyond raising domestic animals to generate income, in particular tea cultivation: in many instances domestic animals do not serve as a farmer's main source of income. Participants indicated that farmers are often very poor.

Field veterinary surgeon-level factors

There are factors that explain the limited number of case submissions to diagnostic laboratories that operate at the level of the FVS: 1) treating based on an animal's clinical signs; 2) making a clinical diagnosis and administering treatment based on that diagnosis; 3) confidence in clinical diagnoses; 4) knowledge of diagnostic laboratory capacity in Sri Lanka; and 5) failure to conduct a gross post mortem examination.

1) Two participants talked about treating cases in the absence of a clinical diagnosis and both talked about treating the symptoms of the disease. One said:

> It is mainly in poultry cases that I cannot identify the cause of disease. If the farmer doesn't like to go to the diagnostic laboratory I treat with broad spectrum antibiotics. I probably have 20 cases in poultry a year in which I haven't identified a proper cause and I primarily treat the symptoms. Sometimes a farmer will only bring one carcass and it will be normal but the other birds still require treatment. In those cases we blindly administer treatment. Mainly cases of decreased egg production, those cases we are treating blindly. (Interview 10, Lines 421-434)

2) Participants frequently talked about making a diagnosis based on an animal's clinical signs, and treating based on that diagnosis. Several interviews contained more than one case example. One participant described the following:

> Normally if a flock of chicken has diarrhea we think it is salmonella or something like that. Based on our suspicion we treat. Most times the treatment is effective. (Interview 1, Lines 113-121)

Another participant said:

> If I need to do lab testing I do. If not, I don't send samples because in normal circumstances I see the disease, confirm the cause, and administer treatment. Then there is no point

> in sending a sample to the lab, and therefore I send few cases to the lab. (Interview 7, Lines 179-181)

3) Participants consistently discussed their clinical diagnoses with confidence. For example, one participant said:

> Most of them [clinical diagnoses] we are sure of. We have more than 10 years of experience, 16 years in fact. Then we are sure. (Interview 4, Lines 265-268)

A few participants demonstrated that they recognize that clinical diagnoses are not always correct. One participant cited the following specific example:

> We are diagnosing distemper in dogs according to their clinical signs. Based on our experience we can examine the dog and decide it has distemper. We are 90 percent correct in our clinical diagnoses. In 10 percent of cases we fail but distemper we can diagnose based on clinical signs. We can diagnose 75 percent of rabies cases but we can't confirm the diagnosis. Sometimes the clinical signs of distemper are the same as those of rabies. (Interview 12, Lines 73-80)

Two participants discussed the potential for misdiagnoses when they apply their diagnostic process. One participant described the following specific case:

> I remember one rabies case in a cow when on the first day I didn't think the clinical picture fit with rabies. The farmer complained the animal was always straining and the farmer told me the cow had eaten the jackfruit. Therefore I told the farmer that because the cow had eaten the jackfruit, it was straining and had bloat. The farmer didn't tell me that there was a dog bite, he didn't notice it. As a result I thought it was an indigestion problem and I treated for that. On the second day the animal had somewhat improved but on the third day the animal collapsed and was straining much more strongly. Then I saw tearing and salivation, all the rabid signs were present. Then I asked the farmer if there was a dog bite and the farmer told me there was a dog bite and rabies was confirmed. (Interview 3, Lines 270-281)

4) Several participants talked about the diagnostic laboratory capacity of VICs. Collectively they referred to the capacity of VICs to perform bacterial culture; antibiotic sensitivity testing; the CMT; blood and fecal parasite identification; the Rose Bengal Plate Test (RBPT); and highly pathogenic avian influenza (HPAI) virus testing. They also indicated that VICs have some ability to produce vaccines. A few participants talked about the diagnostic laboratory capacity of the VRI. According to one participant the VRI has the ability to test for leptospirosis. Another participant indicated that the VRI has the ability to perform bacterial culture as well as PCR and ELISA, though the participant did not state for which diseases the VRI could test by using these techniques. Two participants indicated that they lack knowledge concerning the diagnostics available at the VRI, with one participant stating that this is the result of no interactions with the laboratory.

5) There were a number of different scenarios described by participants during which they did not perform a gross post mortem examination. In the case of death in cattle, a number of participants referred to circumstances under which a gross post mortem examination was not possible. The availability of suitable equipment affected a participant’s ability to conduct gross post mortem examinations in cattle. Distance was also a factor: veterinarians have to travel to the farm to perform a gross post mortem examination in cattle. In certain cases, the carcasses can be too stiff for gross post mortem examination. In some cases farmers do not want veterinarians to open up carcasses, though one participant insisted on gross post mortem examination when animals are insured.

Factors related to veterinary services and infrastructure

There are factors that explain the limited number of case submissions to diagnostic laboratories that are related to veterinary services and infrastructure in Sri Lanka: 1) costs of animal health care; 2) limited availability of supplies, equipment and facilities; and 3) logistical issues related to sample submission.

1) Several participants talked about the costs of diagnostic tests and veterinary services in Sri Lanka. There were marked differences in the cost to farmers reported by participants that varied according to FVS, district, and availability of transportation. There are several FVS payment schemes that depend on the time of day, the availability of government vehicles, and the particulars of the situation. FVSs work normal business hours, but after those hours are able to run private practices. Farmers may have to pay for diagnostic tests but this depends on the type of test and the diagnostic laboratory administering the test. They pay for travel costs if a government vehicle is unavailable. In some instances farmers are charged for drugs only. However, one participant reported that farmers pay for everything: transportation, drugs, and professional fees.

2) Several participants discussed the limited availability of supplies, equipment, and facilities. They referred to a range of items: blood containers; chemicals for diagnostic laboratory tests; pharmaceuticals (including but not limited to antibiotics); surgical instruments; computers; internet access; potable water; facilities for washing after travelling to a case; telephones; and fuel.

3) Several participants referred to logistical issues related to sample submission. Participants referenced a range of obstacles, including limited staff at the veterinary office to transport samples and the tendency for damage to samples during transport. Farmers often make use of bus service to travel to diagnostic laboratories, which presents a challenge. One participant described the following scenario:

> If I visit a case at two or three in the afternoon I must either bring the sample back to the clinic to refrigerate or send the sample directly with the farmer. However this is not possible because the farmer can go but he can't come back to his home because there is no transportation [as bus service does not operate in the evening]. (Interview 2, Lines 22-28)

Many participants talked about transportation issues at multiple points during their interview. Some participants talked about the issue generally, saying things like "it is difficult for farmers to travel" or "transportation is poor", while others were more specific, reporting that they don't have a government vehicle, they have access to a vehicle for a limited number of days in a month, or they can travel only a given distance in a month. Those participants without a vehicle indicated that farmers need to supply some form of private transportation such as a taxi, van or three-wheeler to permit the participant to travel to the farm. When asked about approximate travel times from farms in their DS division to the VIC, several participants gave times ranging from an hour to four hours in one direction. Participants reported travel times from farms in their DS division to the VRI ranging from three to eight hours. A couple of participants stated specifically that they do not know how to address the challenges related to transportation when there is a need to send samples to a diagnostic laboratory.

Theme three: Field veterinary surgeons and surveillance

FVSs and surveillance occurred as a theme in the data, around which were four categories: 1) perceptions of the role of surveillance; 2) perceived limitations of current surveillance methodologies; 3) willingness to participate in surveillance initiatives; and 4) challenges to surveillance methodologies that rely upon FVSs to submit pre-diagnostic data (Table 4.2).

<u>Perceptions of the role and value of surveillance</u>

All participants discussed the role and value of disease surveillance. They talked consistently about surveillance being important to situational awareness, in particular to understanding the disease conditions encountered by FVSs. One participant referred to knowing about common and uncommon diseases. A few participants talked about how surveillance can inform their knowledge and veterinary service activities, including farmer education. Many made reference to understanding geographical variation in disease occurrence while a couple of participants referred to temporal variation.

> From range to range occurrence of disease depends on systems of farming, the medical system, and the climate system. There are so many factors that affect disease conditions. (Interview 7, Lines 369-372)

Understanding geographical variation in disease occurrence can help to inform treatment of disease: surveillance is important for permitting a rapid response to future highly pathogenic disease conditions.

> We have to do more training for the benefit of doing this right because sometimes, like HPAI or in humans

> nowadays there is the swine fever, like conditions will happen in the future so then we can have some idea if some diseases are changing like this, if in England there happened another BSE [bovine spongiform encephalopathy]. In Sri Lanka fortunately we still don't have many diseases but we can't say in the future we don't have right, so we have to be ready for that. (Interview 7, Lines 422-435)

One participant talked in particular about how understanding temporal variation in disease occurrence can guide farmer education:

> If there are a bunch of mastitis cases in a particular month I have to go to the farmers and make them aware that we are going into a month where the mastitis cases are more. I can give some knowledge in cleaning the udder and how to check for mastitis because when they get fresh knowledge sometimes they will do those things. If the mastitis more frequent month is coming I can do it: it wouldn't be high on the earlier months so they will have fresh knowledge and they'll take some precautions to avoid the mastitis. (Interview 2, Lines 489-497)

There were several perspectives about surveillance brought forward by participants including: it is a duty and the main job of veterinarians; it can provide scientific evidence to underpin clinical practice; it is of economic importance in terms of eradicating disease and saving money on vaccination programs; and it can identify zoonotic disease and is therefore important to human health.

Two participants indicated that participating in surveillance initiatives was important to building networks, to understanding the current animal health situation in Sri Lanka, and to having a good communications system in the event of a future highly pathogenic disease condition. They also indicated that it was important to have good relationships with the private sector, industry organizations, and other government departments and ministries. One talked about how networking farmers together was important to disseminating information about disease.

There were a few perspectives brought forward by participants on how best to involve farmers in surveillance. All involved education in some way: prevention and treatment of more common diseases; contagious diseases and how to protect animals; signs of disease for which to monitor; the need to report clinical signs; and animal management. In the case of HPAI, mode of disease transmission, the time it takes for clinical signs to develop and for animals to die, how to protect people from contracting the disease, and the potential consequences of human infection, were highlighted as important areas of knowledge to farmers.

A number of participants talked about engaging members of the public in disease surveillance: three talked about conducting training programs in schools and with farmers about HPAI, in particular about what to do in the event dead birds are found; one indicated it was important to be cautious about the information you provide to the public about infectious disease because individuals could panic and not eat animal products, which would destroy the industry; and one indicated it was important to teach members of the public about risky diseases including leptospirosis, rabies, and HPAI.

Perceived limitations of current surveillance methodologies

Participants believe there are limitations to currently employed disease surveillance techniques. When asked about surveillance programs based on diagnostic laboratory submissions compared to those based on inputs from FVSs, several participants talked about the fact that many cases are not submitted to diagnostic laboratories.

> We are sending the VIC a very small number of cases. Sometimes if we have a problem we call the doctor in charge of the VIC for advice but because the VIC is too far from {town name} we are sending a very small number of samples. I think comparing VIC data with cases seen by veterinarians the big difference is there. (Interview 10, Lines 644-651).

Another participant made the following observation:

> In my case, I can't submit samples most of the time so the labs are not getting any samples so there would be zero value in the lab data. […] Sometimes there may be some misinterpretations, some more misdiagnoses by the vet, because *E. coli* infection and salmonellosis, they would be two different things with the same solution the veterinarians are submitting. There would be some guesses like that. […] Submissions from veterinarians may be wrong compared to the lab but it has some value, more than the lab. It is okay to have the FMD cases in his report other than not reporting. It may be something like FMD, but not FMD, but the veterinarian is suggesting that he is suspecting FMD. It is better to have that mistake, other than have him not report the FMD cases or FMD suspected cases. (Interview 2, Lines 505-513)

Two participants talked about the drawbacks of surveillance initiatives carried out by the VICs: one talked about how VICs conduct sampling at regular intervals but the calves and cows are clinically normal and therefore probably there is nothing to find. The other talked about how VICs are conducting a two-month program in their range but that only three farms are involved.

Willingness to participate in surveillance initiatives

Participants consistently indicated they were willing to participate in disease surveillance. A number of participants discussed incentives for participation in surveillance initiatives and suggested the importance of some form of monetary compensation. Computer and internet access could serve also as an incentive. A few participants indicated that improving infrastructure was important for promoting surveillance.

> Okay, the financial compensation is good but the thing is you can't go into the field without a vehicle. Financial compensation will help to encourage the vet but there are problems with infrastructure, at the same time we have to improve the infrastructure.' (Interview 2, Lines 457-467)

Receiving the results from data collected during surveillance initiatives could serve as a form of incentive. When asked if that would be sufficient incentive in the absence of monetary compensation, one participant responded:

> Getting the information back is good but it will depend on the person who is in the program. When they are interested only then will they participate, the uninterested person will not participate. (Interview 6, Lines 743-752)

Information from surveillance could serve as a form of positive feedback because it summarizes all the cases treated over a given time period, showing how participants positively impacted the industry. Helping farmers reduce their expenses and increase their income was not only reported as a participant's duty, but also provided job satisfaction.

Challenges to surveillance methods that rely upon field veterinary surgeons to submit pre-diagnostic data

In regard to challenges to surveillance initiatives that require veterinarians to input data, two participants indicated they felt there were no difficulties in participating in disease surveillance. In contrast, two participants admitted that they sometimes forget to bring instruments for surveillance into the field. One participant referred to personal factors that impact an individual's participation:

> Some persons who were in this program, they wouldn't have helped you in the data collection. That is a personal thing, that is the nature of the people. Maybe there have been lesser number of cases reported from some ranges, maybe the reason for less cases from a particular range is they have shown less interest in data collection, they are lackadaisical in their habits so they can't be retrieved from their habits. Some people they were really interested and they were willing. Some people didn't have time and some people they can't correct. (Interview 6, Lines 547-560)

One participant stated that FVSs are a little more interested, and feel a stronger sense of obligation to submit information, when the request comes from a foreigner. A couple of participants indicated they felt electronic forms of surveillance were preferred because fewer cases are omitted during the recording process, although one participant admitted that new technology can be difficult to learn at the beginning. Some participants expressed opinions on the topic of their time and surveillance: the time it takes was raised an issue for a few participants, though one highlighted that when there is interest in surveillance time can be dedicated to it.

Discussion

In summary, the results pertaining to FVSs and diagnostic laboratories reveal that participants infrequently utilize laboratories when diagnosing clinical cases. FVSs described circumstances under which they submitted cases to diagnostic laboratories so infrequently in fact that it is difficult to draw any conclusions about the factors that influence FVSs in Sri Lanka to submit cases/samples. Participants were able to describe future circumstances under which they would send samples to a diagnostic laboratory, however there were discrepancies between their future intentions and past experience. The results demonstrate that FVSs use an approach to clinical cases that in most instances does not include diagnostic laboratories. This approach, combined with factors at the level of the farmer, and related to infrastructure and delivery of veterinary services in Sri Lanka, contributes to the potential for missed EID events. Nevertheless, while participants talked in detail about the role of surveillance and the limitations to techniques currently utilized in Sri Lanka, they also indicated a willingness to participate in initiatives that rely on FVSs for data. It is apparent that incentives will need to come in a variety of forms in order to engage FVSs as the motivations behind participation in surveillance varies between individuals.

Field veterinary surgeons' interactions with diagnostic laboratories

The small number of submissions to diagnostic laboratories in combination with the lack of describable case submission patterns by participants has implications if diagnostic laboratories are to be relied upon for detection of EID events. Based on what was learned about FVS practice, change in clinical case load is unlikely to be reflected in the number of diagnostic laboratory case submissions. In the absence of a substantial number of case submissions from the field, diagnostic laboratories are highly unlikely to detect a change in disease burden or receive submissions from individual cases of an EID (e.g., Zurbrigg, 2009). The results show that participants did not have a shared case selection protocol that drove diagnostic laboratory submissions. When there is a lack of common case selection principles driving diagnostic laboratory sample submission, data generated by diagnostic laboratories are unlikely to allow for reliable pattern recognition (M. C. Thurmond et al., 1994; Zurbrigg, 2009). This makes it difficult to interpret the significance of a change in sample submission pattern to the population (M. C. Thurmond et al., 1994; Zurbrigg, 2009).

FVSs have become accustomed to relying on their clinical skills to manage cases and are confident in their current approach. Participants largely used clinical history and examination findings rather than diagnostic laboratory tests to arrive at a diagnosis and guide treatment. Though a few participants employed a hypothetico-deductive method to compile a list of differential diagnoses, the majority used a pattern recognition method based on previous experience to recognize patterns in clinical characteristics that accompany a disease condition. They emphasized that the value of their diagnostic process was in its ability to inform treatment as opposed to its ability to assist the FVS in making a clinical diagnosis. Though no participant stated that they viewed response to therapy as a means of confirming a clinical diagnosis, it did strongly inform their future diagnostic process as well as treatment decision making. This has implications for EID recognition at the level of the individual FVS. A recent review of historical EID events in farm animals found that in many instances an EID event was detected when a clinician was unable to link clinical signs with a known disease, or when a clinician noted outbreaks of unusually severe clinical signs (Vourc'h et al., 2006). Therefore, if FVS focus is toward the treatment most appropriate given the clinical presentation of a case, and there is little consideration given to whether the clinical presentation represents something out of the ordinary at the level of the population, EID events could go undetected by individual FVSs until a time when there is widespread clinical disease and less dramatic events could go overlooked altogether.

Efforts to improve diagnostic laboratory capabilities and the ability of FVSs to utilize them are unlikely to impact these broader challenges to diagnostic laboratory-based surveillance: the results demonstrate that in the vast majority of cases participants arrive at the decision not to submit samples to a diagnostic laboratory. Though all participants indicated that they would like the ability to perform additional diagnostic tests, and described instances when they do send samples and cases assisted by diagnostics, there was no consensus on types of cases that benefit from laboratory diagnostics. In addition, there was no consensus concerning clinical case characteristics that would drive future diagnostic laboratory submissions. The discrepancies between historical diagnostic laboratory submissions and intentions to submit future cases for laboratory diagnostics call into question whether intention will translate into action on the part of FVSs.

As a result of the significant challenges to EID event detection by diagnostic laboratories and individual FVSs in Sri Lanka, the argument can be made that surveillance methods that collect clinical case data from FVSs, and potentially other animal health care workers, could prove essential to EID event detection in Sri Lanka. Data collected could provide a population perspective on the burden of clinical syndromes and diagnoses in domestic animals that currently does not exist. It could allow decision makers to move away from relying solely on individual reports from FVSs and diagnostic laboratories. The data could be combined with that from diagnostic laboratories to inform a variety of animal health-related activities, from EID surveillance to veterinary training to upgrades to infrastructure (Chretien et al., 2008).

Factors underlying the frequency of case submissions to diagnostic laboratories

There were a range of factors that contributed to the infrequency of case submission to diagnostic laboratories by FVSs in Sri Lanka. There were instances when farmers failed to inform FVSs about illness or death in animals and failed to deliver samples to diagnostic laboratories. Farmers faced a variety of challenges that impaired their ability to recognize potential EID events and communicate relevant animal health information to FVSs. At the level of FVSs: symptoms of disease were treated with minimal concern for the underlying cause; many diagnoses were made based on clinical signs; clinical diagnoses were viewed with confidence; there were deficiencies in FVS knowledge concerning diagnostic laboratory capacity; and there were instances where gross post mortem exam was not performed. Lastly, in Sri Lanka there are limitations to the availability of supplies, fees associated with veterinary services, and logistical challenges to diagnostic laboratory sample submission that have direct consequences to the feasibility of case submission to diagnostic laboratories.

Deficiencies in infrastructure make simply increasing the volume of diagnostics tests performed by laboratories unfeasible, in particular at the level of the VRI which is equipped to perform more advanced diagnostic laboratory techniques (refer to Chapter 3, Table 3.2 for a description of the diagnostic laboratory capacity of FVS offices, VICs, and the VRI). However, targeted efforts to improve the likelihood that farmers and FVSs would recognize animal health-related events that could represent an EID risk and perceive the need for diagnostic laboratory testing could improve the quantity of diagnostic laboratory data that is an integral component of Sri Lanka's ongoing disease surveillance efforts. Such efforts would be an important first step in improving the quality and reliability of data resulting from diagnostic laboratory-based animal disease surveillance in Sri Lanka and critical to enabling cases from an EID event to reach the level of the diagnostic laboratory (refer to Chapter 1, Figure 1.3).

Given the situation facing farmers, equipping them with the ability to better recognize animal health-related events of potential significance to human health and an understanding of the impact missing such events could be of benefit. Additionally, some of the barriers that deter farmers from utilizing government veterinary services in Sri Lanka could be addressed. Though a few participants indicated that farmers always contact them when they have a sick animal, the economic status of farmers in combination with the costs associated with veterinary and diagnostic laboratory services reported by participants may mean that farmers in fact do not always alert FVSs of an animal health-related event. Incentives for farmers to engage the veterinary profession could be coupled with education to increase the likelihood that farmers would contact FVSs during an animal health-related event and could include reductions in the costs of veterinary services or relevant animal husbandry training.

The lack of consensus concerning the value of laboratory diagnostics, in particular characteristics of clinical cases that would dictate a need for diagnostic laboratory support, highlights a knowledge deficit among participants. Educating FVSs about clinical presentations in animals that could represent a threat to human health, as well as the value of diagnostic laboratories in addressing these cases, is essential. It is worth emphasizing that though diagnostic laboratory capacity in Sri Lanka is limited and may not be able to identify the etiology of an EID event, it could be used to rule out more common causes of disease. There have been instances where detection of an EID event has been delayed by a concurrent outbreak of an endemic disease. For example, recognition of the 1995 Ebola virus outbreak in the Congo was delayed by a concurrent outbreak of bloody diarrhea caused by *Shigella*, and it has been noted that the ability to rule out *Shigella* in clinical cases of Ebola locally would have been equally as useful as the ability to rule in Ebola virus as the causative agent (S. Morse, 2007).

Field veterinary surgeons and surveillance

Surveillance is a public health practice that is undertaken by people in a wide range of contexts. The practice of surveillance is directly related to the environment in which it takes place and therefore a socio-ecological approach to analysis is warranted in this chapter. There are several versions of the socio-ecological model, however one of the most commonly utilized versions in health research is Bronfenbrenner's (1979) Ecological Systems Theory. It identifies five levels of influence on human behaviour (individual, interpersonal, organizational, community, and societal) that overlap and taken together comprise the environment in which human behaviours take place (Bronfenbrenner, 1979). An assumption inherent to the socio-ecological approach is that assessment and approaches to intervention that operate at multiple levels are more effective in comparison to those that operate on a single level.

Individual-level influences on surveillance

The individual level in the socio-ecological model emphasizes the importance of characteristics of the individuals to intervention strategies. Participants identified surveillance as being important to situational awareness, but many overlooked its public health significance and the decisions and responsive actions it could serve to inform. Educating FVSs about the fundamentals of the surveillance process would be of benefit.

Interpersonal-level influences on surveillance

The interpersonal level in the socio-ecological model emphasizes the importance of social norms and social influences to intervention strategies. Participants have benefitted from the establishment of VICs in Sri Lanka but not because of the increased diagnostic laboratory capacity *per se*: they contact the VIO when they feel it is warranted, either to refer or consult on a case. It is interesting to note that a couple of participants have been quite resourceful in exploring alternative, more proximate, sources of diagnostic laboratory support. A starting point to improve efforts to engage FVSs in future surveillance initiatives would be to strengthen existing networks of communication. One could speculate that by encouraging further development of avenues of collaboration and communication, information concerning potential EID events could be transmitted between and among FVSs and other health care professionals more quickly and participation in surveillance initiatives would be supported within the veterinary profession (e.g., Maher, van Gorkom, Gondrie, & Raviglione, 1999; Ndiaye et al., 2003; Obregón & Waisbord, 2010). This approach would be feasible given that Sri Lanka is a lower resource setting as it relies on existing human resources within the community (Maher et al., 1999; Ndiaye et al., 2003; Obregón & Waisbord, 2010).

Organizational-level influences on surveillance

The organizational level in the socio-ecological model recognizes that changing the policies and practices of a workplace can serve to support behavioural change. In Sri Lanka, providing VIOs with additional means to support the activities of FVSs, as opposed to focusing solely on enhancing the diagnostic capacity of VICs, is one form of incentive that remains unexplored. Stronger networks would support such efforts through dissemination of current data and information and reinforcement of learning objectives, as well as provide a continuous means of encouraging ongoing participation in surveillance (Maher et al., 1999).

Community-level influences on surveillance

The community level in the socio-ecological model recognizes that coordinating the efforts of members of a community, in this case FVSs, is necessary to bring about change. The willingness of participants to engage in surveillance activities highlights that FVSs represent an underutilized opportunity to improve EID event detection. However, the lack of shared view on incentives for participation remains a challenge. Surveillance program incentives will need to serve the motivations of a range of individuals. Future programs should consider some form financial compensation for the time dedicated by FVSs, along with infrastructure support and data feedback, so participants are able to see the benefits of their efforts (Maher et al., 1999). Administrators of surveillance programs will need to demonstrate to FVSs that dedicating time and effort to surveillance is worthwhile and the results are of significance to farmers and the veterinary profession.

Societal-level influences on surveillance

The societal level in the socio-ecological model recognizes that there are societal or cultural high-level factors that create a climate that encourages or discourages behaviours. Broadly speaking, governments and the public health community create a climate that impacts ability and willingness to report EID events. This process is operating at the level of nations, animal health care workers, and farmers. In the context of Sri Lanka, in order to reap the benefits of efforts to network and educate farmers and FVSs, these individuals will need to feel empowered to report clinically suspect situations in animals to those with the ability to act, and rewarded for their efforts. At the very least, fears of negative consequences of reporting will need to be addressed. Other research has shown that punishment for reporting of animal health-related events needs to be avoided as it will serve only to undermine efforts to strengthen participation by veterinarians and farmers (Elbers, Gorgievski-Duijvesteijn, Zarafshani, & Koch, 2010).

One of the major challenges in the Sri Lankan context is deficiencies in transportation and infrastructure: the state of local transportation, in particular the rail and road network and availability of public transport, combined with the number of people the system needs to accommodate, makes travelling any distance a cumbersome and time-consuming endeavour. The results indicate that this impediment is a significant barrier and could undermine efforts at other socio-ecological levels to improve surveillance.

Delays in disease reporting are considered a worldwide problem (Jajosky & Groseclose, 2004; S. Morse, 2007; Reijn, Swaan, Kretzschmar, & van Steenbergen, 2011; Yoo et al., 2009). Recent examples in which countries were slow to report include the outbreak of SARS and highly pathogenic H5N1 influenza virus (S. Morse, 2007). Apprehension concerning the consequences of infectious disease outbreaks to trade, travel, economic growth, as well as fear of embarrassment, contributes to these delays (S. Morse, 2007). Reporting of EID events is essential to protecting public health. However, disincentives to reporting persist and incentives are lacking (S. Morse, 2007). Future surveillance initiatives need to incorporate an enhanced understanding of the human dimension of surveillance to be most efficient and effective.

Table 4.1: Open-ended questions and follow-up probes used during veterinarian in-depth interviews

Discussion topic	Key question and follow-up probes
Decision making around diagnostic laboratory submissions	Please describe the various factors that affect your decision to submit samples for laboratory diagnostics. • What do you see as the benefits of laboratory confirmation? • What are the costs of sample submission? • Are there instances where laboratory testing is more warranted – or less warranted? What influences this? • When it comes to sample submission who is the final decision maker in the process? • What kind of value does laboratory testing provide? • Are there types of cases in which you feel laboratory testing is more urgent? • Do you have particular 'flags', 'indicators', or scenarios that prompt you to consider laboratory testing more carefully? • How does your familiarity with the species or syndrome affect your decision? • Do you think your decision-making process behind the submission of samples to labs has changed over time? • Do you think you're submitting the same types and numbers of cases to laboratories as you were when you started in practice? • How many diagnostic tests are you running in your clinic versus submitting to an outside lab?
Participation in disease monitoring and surveillance	Please talk to me about how willing you think veterinarians are or would be to participate in a disease monitoring and surveillance program. • What are the obstacles to participation? • What are the potential benefits? • Is there conflict between the different roles veterinarians are supposed to play and the interests they are compelled to adhere to or represent? • Should veterinarians be more engaged in disease monitoring and surveillance? • If yes, how might this be accomplished? • Do you think veterinarians have additional infectious disease information to provide that may be missed by diagnostic laboratory based surveillance?

Discussion topic	Key question and follow-up probes
Disease monitoring and surveillance and farmer interactions	Do you discuss disease monitoring and surveillance with farmers? • Please talk to me about the range of attitudes you encounter, using specific examples wherever possible. • How do you address concerns farmers have about the consequences of infectious disease identification? • What do you see as the potential benefits to such conversations? • What do farmers see as their role in disease monitoring and surveillance or do they see themselves as having a role at all? • How concerned about the potential for disease outbreaks do they appear? • How do you think farmers could be better engaged in disease monitoring and surveillance? • Are there other members of the community that could be more effectively engaged in disease surveillance?

Table 4.2: Research aims linked to the themes and categories that emerged during data analysis

Research aims	Themes	Categories
Advance understanding of the factors that influence government field veterinarians in Sri Lanka to submit cases to a diagnostic laboratory	Field veterinary surgeons' interactions with diagnostic laboratories	The reported frequency of submissions to diagnostic laboratories
		Cases from which samples were submitted
		The tools employed in making a diagnosis
		Perceived benefits of diagnostic laboratory assistance
		Desire for further diagnostic laboratory capacity
		Future diagnostic laboratory submissions
	Factors underlying the frequency of case submissions to diagnostic laboratories	Farmer-level factors
		Field veterinary surgeon-level factors
		Factors related to infrastructure in Sri Lanka
To describe the complex of factors that affect ability and willingness of government field veterinarians in Sri Lanka to participate in EID surveillance programs	Field veterinary surgeons and surveillance	Perceptions of the role and value of surveillance
		Perceived limitations of current surveillance methodologies
		Willingness to participate in surveillance initiatives
		Challenges to surveillance methodologies that rely upon field veterinary surgeons to submit pre-diagnostic data

CHAPTER 5: FACTORS INFLUENCING ALBERTA CATTLE VETERINARIANS' DECISIONS TO SUBMIT CASES TO DIAGNOSTIC LABORATORIES AND THEIR WILLINGNESS TO PARTICIPATE IN PRE-DIAGNOSTIC SURVEILLANCE INITIATIVES

Introduction

In Chapter 4, the concept that diagnostic laboratory sample submitters introduce selection bias into the process of determining disease patterns occurring in the animal population from patterns detected by diagnostic laboratory-based surveillance was introduced. In high-resource settings, veterinarians are often the primary decision-makers in the process that determines which cases will be submitted for diagnostic laboratory testing. Therefore, in order to understand the selection bias in diagnostic laboratory-based surveillance in these contexts, submission patterns of veterinarians and the factors that influence their decision to submit samples must be better understood (M. C. Thurmond et al., 1994; Watson et al., 2008; Zurbrigg, 2009).

The rationale for the need for enhanced surveillance for EIDs was presented in Chapter 4. In Alberta, in response to the need for early detection of EID events in the animal population, the Department of Agriculture and Rural Development (ARD) has developed the Alberta Veterinary Surveillance Network (AVSN), a multifaceted surveillance program that enables producers, private veterinary practitioners and animal health authorities to respond to disease issues in the domestic animal population (Government of Alberta, Agriculture and Rural Development, 2010). One component of the program is the Alberta Veterinary Surveillance Network-Veterinary Practice Surveillance (AVSN-

VPS), a secure internet-based platform that allows cattle veterinarians to submit pre-diagnostic disease and non-disease case data to a centralized system. The AVSN-VPS is considered integral to the AVSN as it informs the activities of other program components including disease investigations by ARD pathologists, epidemiologists, and surveillance veterinarians.

The success of the AVSN-VPS is dependent upon ongoing participation by private veterinary practitioners in Alberta. It began in 2005 with thirty cattle veterinarians, and now includes greater than fifty percent of cattle veterinarians in Alberta (J. Berezowski, personal communication). Practitioners receive monetary compensation for submissions that are received by the AVSN in a timely fashion and participation is voluntary (J. Berezowski, personal communication). In order for methods that rely on data inputs from private veterinary practitioners to improve, continued involvement by these individuals is essential. The factors that inspired these practitioners to become involved in the AVSN-VPS are unclear, as are the reasons for ongoing involvement.

Qualitative research is becoming increasingly common in the animal health field (Coe et al., 2007; Hektoen, 2004; M. Vaarst et al., 2003), however qualitative studies are rare in comparison to the frequency of quantitative studies. In Chapter 4 I demonstrated the value of employing qualitative methods in understanding the human dimensions of diagnostic laboratory case submissions and participation of government veterinarians in pre-diagnostic disease surveillance initiatives in Sri Lanka. There are, however, challenges to animal and human health care services that are unique to lower resource settings like Sri Lanka (Chen et al., 2004; Petti, Polage, Quinn, Ronald, & Sande, 2006). Also, there are differences in the delivery of veterinary services in Alberta compared to Sri Lanka that are of consequence to diagnostic laboratory submissions and veterinary participation in pre-diagnostic surveillance systems (Umali, Feder, & Haan, 1994). In Alberta veterinary services are delivered by the private sector while in Sri Lanka veterinary services are delivered by a mixture of the public and private sectors. The concern for EIDs is not restricted to lower resource settings. Canada's experience with HPAI, bovine spongiform encephalopathy (BSE), and SARS highlights that EIDs are a global phenomenon (Wagner et al., 2006) and understanding the capacity of surveillance systems to detect EID risks in animals is necessary across a range of resource contexts.

In this chapter I report the results from a focused ethnographic study that aimed to advance understanding of the factors that influence cattle veterinarians in mixed-animal and cattle private veterinary practice in Alberta to submit cases to a diagnostic laboratory, and to describe the complex of factors that affect the willingness of these veterinarians to participate in surveillance programs. The results reported here are intended to inform thinking about disease patterns reported by diagnostic laboratories in settings where veterinary services are a provision of the private sector and improve efforts to engage private-sector veterinarians in high-resource settings in pre-diagnostic surveillance initiatives.

Materials and Methods

Study design

This is a focused ethnographic study composed of in-depth interviews with participants linked by their experience as cattle veterinarians in private veterinary practice in Alberta who were also participants in the AVSN-VPS (refer to Chapter 4 for a description of focused ethnography).

For the purpose of this study, veterinary disease surveillance is defined as continuous efforts to collect, collate, and interpret information about the health and disease status of a defined animal population, wherein information is disseminated to those responsible for public health actions taken in response to changes in the animal population deemed significant (Doherr & Audige, 2001; Höhle et al., 2009). Context is defined as the circumstances, including personal, community, economic, political, social, cultural, epidemiologic, and regulatory, in which disease surveillance is being performed (Fetzer, 2004; Leibler et al., 2009). In-depth interviews were conducted from October to December 2009. The Conjoint Health Research Ethics Board at the University of Calgary approved the study proposal (Ethics ID number 5136).

Study participants

Eligible participants included veterinarians that were participants in the AVSN-VPS at the time the interviews were conducted. Dr. Jagdish Patel, whose responsibilities included administration of the AVSN-VPS within the ARD, initially approached participants. He gave them a brief description of the research project and format and asked if they would allow their contact information to be shared with the researcher (KES). Potential participants were told that KES is a veterinarian who continues to work in clinical practice while enrolled in a graduate program and worked previously in a mixed-animal practice in Alberta. This explanation was intended to facilitate access to further information by conveying that KES has some prior understanding of the challenges faced by veterinarians providing clinical services to the Alberta cattle population. During the following four weeks, KES contacted veterinarians that had agreed to share their contact information and provided them with a more detailed description of the research. There were only eleven prompt responses to the request for sharing of contact information and therefore the decision was made to contact eligible participants as responses were received that indicated a willingness to participate. Eligible participants were characterized by sex, number of years in practice, practice location and type. From the final group of fourteen eligible participants that initially responded, ten were purposively selected to take part in in-depth interviews with the aim to assemble a group of participants with maximum demographic variation in the characteristics listed previously, with an additional two selected should further in-depth interviews be required to achieve data saturation. Descriptive statistics were used to summarize the characteristics of the study participants. In order to maintain participant confidentiality, practice locations were not detailed.

In-depth interview structure

The ten selected participants were contacted individually to schedule times for interviews. In-depth interviews were conducted at participants’ locations of choice: most often this was an office space in their veterinary practice except for three interviews that were conducted over the telephone because of the long distance between KES and the three participants. Prior to the interview, each participant reviewed and signed an informed consent form. Participants were asked at the beginning of the interview to confirm orally that they had signed the consent form. Each in-depth interview, conducted by KES, was no longer than 2 hours in length. A semi-structured format with a series of standardized open-ended questions was used (Table 5.1). An initial set of follow-up probes was drafted and employed where appropriate: probes evolved as additional interviews and preliminary analyses were conducted (Table 5.1).

All in-depth interviews were recorded using two digital audio recorders. At the end of each interview the recordings were downloaded onto a password-protected laptop computer. Both audio files were reviewed to ensure the interview had been recorded in its entirety. One file was then sent to a professional transcriptionist who transcribed the interview verbatim from the audio recording. Personal identifiers were removed from the transcribed files to ensure participants' responses remained anonymous. One of the telephone interviews, the fifth interview in the series, failed to record. The error was noted immediately following the conclusion of the interview. The researcher immediately updated the field notes to document all data that could be recalled from the interview to enable revision of the probes used in subsequent interviews. As a result of this occurrence only nine interview transcripts were available for analysis.

After transcription of the first two interview audio files, the data were coded by interview question using NVivo 9 (QSR International, Australia), a qualitative analysis software suite that enables researchers to organize and retrieve qualitative data, including textual material, to get a sense of the data set as a whole. The probes were then reviewed and revised based on the data from the first two interviews. After the third and fourth interviews this process was repeated: the audio files were transcribed, the transcriptions were reviewed, and the data was coded by question. The probes were again reviewed and revised in light of the data from the first four interviews. The probes were reviewed and revised a third time after the fifth interview. The remaining five interviews were conducted during a three-week time period during December 2009, which did not allow for transcription of the audio files between interviews. However, field notes were reviewed after each interview which informed the probes in subsequent interviews. Collection of interview data concluded after the tenth interview.

Data accumulated in addition to the in-depth interview transcripts included: memos made by KES to document decisions made in the data collection and analysis process, day-to-day activities, and any comments concerning the methodological approach; a reflective journal kept by KES further describing the research process and the researcher's experience with participants; and field notes used to record any observational data. Memos and the reflective journal were captured directly in Microsoft Word (Microsoft®, USA) while field notes were made directly onto the interview guide during each interview and later transcribed. All raw data and material arising from the research activity were scanned into electronic files and the original documents destroyed. A single copy of the original interview audio files was transferred onto a password-protected DVD and the original files were removed from the laptop computer. The electronic version of these materials is being stored by Craig Stephen, Principal Investigator and Doctoral Supervisor, for seven years as required by the University of Calgary's Faculty of Medicine Research Policy Guidelines for Integrity in Scholarly Activity.

Data analysis

The first step of analysis of the transcripts from the in-depth interview audio recordings involved reading through all of the transcripts to get a sense of the data set as a whole. Thematic analysis (Graneheim & Lundman, 2004) was performed on the transcripts. During the process of thematic analysis, data were systematically organized within NVivo 9 using codes that KES inductively derived from the records. The goal was to identify concepts, categories, relationships, and themes. Themes, concepts, codes, categories, and relationships were developed and defined a described in Chapter 4. All of the codes were reviewed to ensure the concepts, categories, themes, and relationships between them were completely and appropriately described. All data presented in the results section reflect the observations, insights, and opinions expressed by participants. Following analysis of the nine interview transcripts it was determined that data saturation had been achieved and therefore no further in-depth interviews were conducted.

Trustworthiness is pursued as part of qualitative research studies. The aim is to demonstrate that the findings are 'worth paying attention to' (Lincoln & Guba, 1985; Shento, 2004). In order to establish trustworthiness in qualitative research studies four criteria have been proposed: (i) credibility (preferred over internal validity, a criteria employed by quantitative investigators) (ii) transferability (comparable to external validity/generalisability, a criteria employed by quantitative investigators); (iii) dependability (comparable to reliability); and (iv) confirmability (comparable to objectivity) (Shento, 2004). My approach to assessing these characteristics in this chapter was identical to that described in Chapter 4.

Results

Study participants

Study participants were located in a variety of practice settings in all areas of the province of Alberta. Each participant came from a different veterinary practice; two participants were female (20%). Veterinarians had from two to 38 years (median, 24 years; mean, 22) of clinical experience. Nine (90%) veterinarians were in mixed-animal practices, while one was exclusively in food-animal practice. Further details on the study participants are not provided to protect their identities.

Overview of the themes and categories (Table 5.2)

Analysis of the data collected during the interviews revealed three themes: 1) veterinarians and diagnostic laboratory submissions; 2) veterinarians and surveillance; and 3) the veterinary perspective. Table 5.2 summarizes the themes and their associated categories, and relates them to the core research aims of this study. Themes and categories are described in detail below each of the theme headings.

Theme one: Veterinarians and diagnostic laboratory submissions

There were five categories identified that relate to cattle veterinarians in Alberta and their diagnostic laboratory submissions: 1) factors that encourage diagnostic laboratory submissions; 2) benefits realized through diagnostic laboratory testing; 3) limitations of diagnostic laboratory testing; 4) economic considerations related to diagnostic laboratory submissions; and 5) characteristics of diagnostic laboratory submissions (Table 5.2).

Factors that encourage diagnostic laboratory submissions

Participants reported a range of factors that encouraged them to submit cases to a diagnostic laboratory. Herd-level promoters included: outbreaks where the participant was unsure of the cause; unusual rates of mortality; and potential herd-level implications of the problem. In many instances participants wished to confirm the clinical diagnosis or know the cause of the disease. Participants targeted: particular syndromes of interest; cases with poor response to treatment or pharmaceutical produce failure; cases where results from diagnostic laboratory testing would inform clinical practice; cases where there was no diagnosis from clinical or gross post mortem examination; cases where there was a suspicion of a notifiable or reportable disease; atypical case presentations; cases where the economic consequences of disease were potentially high; cases in which there was a potential public health risk; cases involving high-value animals; bizarre cases; and insurance cases. Participants also submitted samples to a diagnostic laboratory at the request of owners/producers and in instances where it was convenient. A case condition emphasized by all participants was the importance of multiple animals affected.

> The most critical thing would be the value of the information to me and to the client, and the value that might be gleaned from a submission. We don't normally submit samples from routine necropsies or from cattle clinical exams unless we feel there's either an urgent need to do so […] Situations where we would see obvious urgent need would be multiple sudden deaths, recurring problems within a herd, we decide to do a little more in-depth investigation but typically our routine stuff doesn't qualify under our protocols for laboratory testing. (Interview 10, Lines 3-4)

Participants emphasized that the decision to submit samples depended on the context:

> [More than expected disease] Depending on the type of operation they're [producers] running, depending on how well vaccinated the cattle are. I mean some guys backgrounding cattle aren't doing anything, so if I've got five or six calves out of 50 that are dying, that's not unexpected. If I've got a well-vaccinated herd and good management and good mineral program and good nutrition program and I've got more than two or three that are sick out of 40 or 50, then I'm concerned so I guess it depends on the producer part within the management. Better management, better managed herds have less disease but usually those kind of people usually we do more diagnostic stuff because they want to know whereas the poorer managed ones save money on management costs so they can afford to have more losses. (Interview 6, Lines 40-47)

Several participants stressed that they were more likely to pursue diagnostic laboratory testing when the results impacted case management:

> You know, you asked me back there do I always leave it up to the client, whether they do diagnostics or not, and I guess I don't. It depends what I'm dealing with. If there's something that I can't answer the question without this, and I believe that this test is going to give me the answer, then it's just I need to do this. If it's something that is academic again, it may have some benefit or it may not and the cost is significant, then it goes back to the client to decide. I guess ultimately it comes down is that, my reason for testing is, is it going to change my therapy when it comes

> to beef. Yeah, and if it's not going to change my therapy, then it's academic. (Interview 7, Lines 128-134)

<u>Benefits realized through diagnostic laboratory testing</u>

The benefits of diagnostic laboratory testing referenced by several participants included: enabling a definitive or etiological diagnosis; facilitating participant learning; improving confidence; and informing cases in which there are legal concerns. When participants talked generally about arriving at a definitive or etiological diagnosis, they most often referenced cases from which it would be nice to submit samples to a diagnostic laboratory, as opposed to particular cases from which samples were sent.

> I think a lot of times lab testing would be indicated. If you're doing a post mortem on a pneumonia it would be wonderful to determine what etiology is causing that pneumonia. Even a blackleg calf, it would nice to do a sample on that. If you have a calf that you suspect has lead toxicity, it would be nice to send samples in for that so I think the majority of cases that we do, it would be wonderful to be able to send samples in and come up with a definitive diagnosis. (Interview 3, Lines 51-53)

On the subject of facilitating learning and building confidence, one said:

> I think that, in my position at least, as a new grad coming out…, you get a lot of that counter talk where it's "this is what's going on, what do I do about it" and you have no confidence because cows are hard to diagnose things in anyways because they hide it well, so you get talking to somebody and it could be four different things and you have no idea and it would be nice to be able to confirm something. Even if it's just for diagnostic purposes, for the back of your mind for the next conversation that you have six months or eight months down the line and say okay well I remember dealing with so and so and it was this and the clinical signs seemed to be roughly the same so even if you don't see that animal the second time, you can go okay well you've got it in your memory bank that you confirmed

> something on the last one, right? I think that in terms of developing a rural mixed animal practitioner that is actually going to stay in rural mixed animal practice, it's extraordinarily important to be able to have the confidence in your ability to figure out what's going on and I think that's a huge part of retaining vets in these types of practices. (Interview 8, Lines 71-86)

Limitations of diagnostic laboratory testing

Participants also talked about the limitations of diagnostic laboratory testing. Several mentioned that in many cases unanswered questions remain even after diagnostic laboratory testing has been completed.

> Sometimes it's a little bit frustrating because you can't get the answers you want. We don't have the testing capabilities at some of the labs sometimes. I think back to some of the *Clostridium* issues and I know it's been a debated pathogenesis for some time with ulcerated abomasums in calves and abomasitis and I firmly believe that it's *Clostridium* as one of the major organisms in that but truly getting it typed and knowing what specific bacteria is there can't be done. […] I remember having a discussion a long time ago with one of the pathologists up in Edmonton and in this particular case the calf died as I walked across the pasture and I did a quick post [mortem] on it and it had a perforated abomasal ulcer and all the way around the ulcer was emphysematous tissue within the mucosa of the abomasum and I have the suspicion *Clostridium* is playing a role and I've got my tissue here. This isn't post-mortem, this was pre-mortem. I shipped it off to the lab and sure enough they cultured *Clostridium* and that's all they could do. They couldn't take it any further than that and so I was talking to the pathologist I said "There, see, I knew *Clostridium* was playing a role" and he says "yeah but chicken or the egg? Did the *Clostridium* invade an ulcerated tissue or was it the cause?" Okay, fair enough, you've got me on that one but we'll keep looking. A couple of years later another calf came in, this is when we were still operating on calves because the value was there. From the outside you could see this calf

> had abomasal pathology and I opened up the abomasum to resect what I suspected was an ulcer, and the abomasum itself had multiple plaques varying in size from probably about a couple of centimetres to ten centimetres of emphysema. No visible ulcers anywhere. There were plaques all over that abomasum… There was the *Clostridium* invasion, the emphysema you could see right in the mucosa, no ulceration, … so again I think that it is likely the primary [problem] going on but there may be predisposing factors. The frustrating part is that you could never get past a *Clostridium* species. I couldn't go any further than that. We were using *Clostridium* vaccines to try and help prevent this, vaccinating cows and calves, and still would have issues (Interview 7, Lines 44-54).

A number of participants mentioned that the time lag between when samples are sent to a diagnostic laboratory and when results are available is a limitation.

> It'd sure be nice to have results immediately and obviously you can't but if you could say "I suspect this animal has *Pasteurella* pneumonia" and you take a sample and you stick it in a machine and five minutes later you have your diagnosis, that would be the ideal situation but obviously that's not the case. That lag time does create a bit of a challenge because the farmer wants you to give him some advice immediately, "I'm losing calves, I'm losing animals, what do I do now?" rather than take the samples and wait for a week, "I need some advice now" so a lot of these lab results are sort of to confirm what you've made your diagnoses on and what you've based your treatment advice on. (Interview 3, Lines 78-87)

A few participants talked about the challenge presented by degradation of carcasses and tissue samples in the field such that by the time samples are collected they have degraded to a point where they are unsuitable for many diagnostic laboratory tests.

Economic considerations related to diagnostic laboratory submissions

All participants talked about economic considerations that impact their decision to submit samples to a diagnostic laboratory, often at multiple points during the interview: diagnostic laboratory testing needs to be worthwhile from the perspective of producers; diagnostic laboratory testing is cost prohibitive for producers; and the economic reality of producers means that in the majority of instances samples are not submitted to a diagnostic laboratory. As one participant explained:

> A lot of it is driven around economics these days. I guess the primary reason behind diagnostics is when I can't figure it out on my own… We try to make clinical diagnoses or gross post-mortem diagnoses whenever possible […] When we are faced with outbreaks that we're unsure of what it is we'll do lab work. Every now and then when I get a case that's not quite as straightforward as most of them, I'll do lab work. In the cow/calf part of our practice we'll submit lab work on most fetuses that we autopsy and I guess any outbreak situations where either we might change our vaccine program or treatment program based on the outcome we'll go ahead and do lab work but there's always a reason for doing it other than just casually wanting to know… We need to make sure we're spending our client's money judiciously. (Interview 1, Lines 2-3)

Another participant described how the economics of the cattle industry makes diagnostic laboratory testing cost prohibitive and translates into small numbers of diagnostic laboratory submissions:

> Look at your cow producer and your horse producer. If your cow has got a skin lesion, they're going to try everything under the sun first whereas a horse person would say "oh yeah biopsy this or send it away, not a problem." They're not going to put 150 dollars of a test plus treatment into a cow that's worth 100 bucks or whatever. […] Because of the way the market is right now, you're getting less people even bringing stuff into the clinic

> and more people just coming in and asking questions about what they can treat it with at home. People don't even want an exam let alone take lab samples to send away and it's harder and harder to get on those farms because then they're paying you for an exam and mileage and there's just not enough money out there right now for the cattle side. A lot of what you see is on farm looking at the rest of the herd and what's going on and you know I think that that's lacking because of economics. It's too bad because I'm sure we're missing a lot of things or perhaps there's other diseases going on there even in terms of… simple straight pneumonia or scours ripping through the herd. If you don't get to see what's going on on-farm, you're kind of treating individual animals when it may have a herd basis to whatever disease it is you're dealing with so I think we're probably missing a fair bit. (Interview 4, Lines 25-29)

When asked about costs in addition to the monetary costs of sending samples to diagnostic laboratories, one participant replied:

> There is… a social cost or a reputation cost associated with sending them. People take pride in their animals and take pride in their herds and they like to have a healthy strong vibrant herd. They don't want to have something in there that's going to be a concern to them, […] they don't want to have a herd that's going to decimate the industry and they don't want to have a herd that they're not proud of that they're always looking for illness or issues - I think those are the non-monetary costs. (Interview 9, Lines 9-10)

<u>Characteristics of diagnostic laboratory submissions</u>

Several participants indicated that they are submitting fewer cases to a diagnostic laboratory over time. This was attributed to a variety of factors: as you move along in your career as a veterinarian there are fewer things you have not seen; the value of cattle has decreased, making it more difficult to submit samples; and decreases to government support for diagnostic laboratories and a decline in access to diagnostic laboratories means that submission patterns have become increasingly selective. A number of participants provided an estimate of the frequency of submissions, with rates reported between one case out of 10 to one case out of 100:

> 1 percent of the time. Very, very rarely. I have not sent anything this year and we're most of the way through the fall run, it's basically over. I've talked to lots of guys about lots of sick calves this fall and have not sent one thing in, have not done one post-mortem. […] And we've not sent a sample away. (Interview 8, Lines 35-40)

Several participants referred to changes to the diagnostic laboratory infrastructure in Alberta, in particular reductions to the provincial veterinary diagnostic laboratory system, with the result being fewer submissions to diagnostic laboratories.

> If you wanted a quick answer, you'd send it to the private lab. If you wanted a slow answer, low cost, you'd send it into the public system and then eventually the public system just phased right out. Then for sure the submissions dropped off. Now while that private lab functioned, they were primarily large animal pathologists, a lot of stuff was still sent up there but that lab has changed and was bought by Central, so the emphasis is not on the beef side anymore. I mean that's less and less of the practice so when that happened, then we started using PDS [Prairie Diagnostic Services, a diagnostic laboratory in Saskatchewan] more even though it was longer, ..at least a day longer [...] It's [the decrease in sample submissions] multi-factorial. One is decreased numbers. The other is the clinicians were not large animal clinicians […] so the answers coming back often were not all that helpful. I would get better answers when I submitted tissue to PDS. But PDS again was a delay and so you really had to look at it and say okay, is this still going to be of any benefit to me by the time I get my answer. (Interview 7, Lines 107-122)

Many participants reported that it is the producer that is the final decision maker when it comes to submitting samples to a diagnostic laboratory, while two stated that they (veterinarians) act as the final decision maker. A number of participants discussed the ability of veterinarians to influence the decisions made by producers.

> I think one of my roles is truly to make sure that they [producers] make an informed decision. We kind of talked about the idea that I didn't have to come up with a plan and decide how much their cow was worth and how much they could spend without even talking to them as they need to decide that part. […] I mean I am the one that's the most informed and they would trust which direction I suggested they go. […] So my job is to try and inform them as much as possible so "if you take this set course of action, here's the possibilities". (Interview 7, Lines 354-357)

Theme two: Veterinarians and surveillance

Veterinarians and surveillance occurred as a theme in the data, around which were six categories: 1) willingness to participate in surveillance initiatives; 2) veterinarians ought to participate in surveillance; 3) drivers for involvement in surveillance initiatives; 4) gains from the involvement of veterinarians in surveillance; 5) participants' perceptions of the role for government in surveillance; and 6) participants' perceptions of the role of surveillance (Table 5.2).

<u>Willingness to participate in surveillance initiatives</u>

All participants expressed the belief that veterinarians are willing to participate in surveillance. However, attached to this willingness were a number of caveats: there needs to be feedback of information which has value in participants' clinical practice; data submission cannot be too time consuming; participants need to be compensated for the time they dedicate to collecting data; the data collection process needs to be convenient;

and in order to motivate ongoing involvement administrators of surveillance programs should demonstrate the relevance of the data collected. Participants cited time and effort as the costs of surveillance they incur.

Veterinarians ought to participate in surveillance

Participants expressed frequently the opinion that veterinarians should take a more active role in surveillance. When asked if veterinarians should be more involved in disease monitoring and surveillance, one participant replied:

> You bet. I think everyone should. I think again it comes back to a bit of a responsibility to you as a veterinarian. I think the idea of shoot, shovel, shut up type thing is just the wrong approach to take. You can only solve the issues if you know what the issues are and report it, find out what it is, go further. (Interview 7, Lines 312-316)

Drivers for involvement in surveillance initiatives

When asked about why they opted to participate in surveillance initiatives, including the AVSN-VPS and the BSE surveillance program in Alberta, participants cited a number of drivers behind involvement: monetary compensation; information generated and fed back through the program; interest in surveillance; perceived value of the program; and access to additional diagnostic laboratory services. The first two drivers came up frequently across different interviews. A couple of participants emphasized that while monetary compensation is important to offset the time it takes to participate, it does not serve as a motivator in and of itself. One participant discussed how drivers vary among veterinarians:

> Money talks. […] The BSE program is a good example of that. If you pay people, the right people, the job will get done. I think you'll get a core group of preventers doing it out of the goodness of their heart because they're interested in it and they think it's a good program but if you want to get more people on board, if you somehow reward them economically, then people do it. (Interview 3, Lines 163-167)

On the subject of information and additional laboratory support, one participant stated:

> I think that it provides us with some information and it provides us with access to some lab services in those situations that's difficult so not only do we get some surveillance information throughout the province or the region but we also have access if we need it to some pathology should we run into some of these situations regarding undetermined and non-responsive diseases […] We use those because we can go to the producer and encourage him to take those steps and do those diagnostics without having a big cost incurred because diagnostics are expensive. If we send them out, they're expensive and we want to make sure that we're getting good value for the producer and by participating in the surveillance network, it gives us an avenue that we can look at some of these diseases in more detail. (Interview 9, Lines 69-71)

When participants talked about information they received through surveillance initiatives, they discussed the importance of receiving that information but a few said they do not often access the outputs from the AVSN-VPS.

<u>Gains from the involvement of veterinarians in surveillance</u>

All participants talked about gains through the involvement of veterinarians in surveillance. Participants highlighted that: the AVSN-VPS could be used to inform diagnostic laboratory-based surveillance; the AVSN-VPS received a greater number of submissions compared to diagnostic laboratories; and the AVSN-VPS was timelier in comparison to laboratory-based surveillance. A couple of participants talked about past cases where the AVSN-VPS informed diagnostic laboratory-based surveillance, but more expressed the view that they would be more engaged, and the program could be improved, if there was more diagnostic laboratory support provided through the program:

> I think what we could do is we could decide what types of animals we're interested in monitoring or doing disease surveillance on. I think the food animals…, it's obviously going to be within that [population]. We could probably decide what clinical signs we're interested in pursuing, whether they would be of value in helping predict zoonotic problems or whether it would just help to keep the health of the herd intact but either one of those. I don't think it would be that difficult to sit down and come up with sort of a list and maybe even a decision tree for diagnostics that the government would subsidize. (Interview 1, Lines 65-66)

Participants felt frontline pre-diagnostic disease surveillance was vital to understanding disease trends, was essential as a marketing tool, and assisted in identification of outbreaks:

> It does allow us to identify outbreaks or I think it allows us to identify new syndromes. […] Within a practice you're going to know about an outbreak but I think it'll also help identify whether there's any disease trends within the province and last but certainly not least, I think it plays very well as a marketing tool for our export markets. I think the ability to show that we have a progressive surveillance system in place for animal health bodes well for controlling zoonotic diseases and marketing our products internationally. (Interview 1, Lines 55-56)

When asked if frontline surveillance that uses veterinarians to supply data provides information beyond what is being collected from diagnostic laboratories, one participant responded:

> Yeah. […] With our experience we don't submit a lot of diagnostics because of the producer having to pay for it.

> […] We're going on what we think the disease is half the time. The diagnostic labs are great and they come up with an answer on stuff that's submitted but I would hazard a guess that whether it be a clinical exam or a post-mortem specimen or whatever, it might be one time out of fifty that I submit stuff to the diagnostic lab. It's pretty minimal. I believe that the AVSN [AVSN-VPS] "A" even if you use a diagnostic lab, it's going to be quicker… Now it may not always be the right one but you're going to be a week ahead of the diagnostic lab for sure and nineteen times out of twenty, I won't say one out of fifty, it's not getting submitted to the diagnostic lab anyway. The real oddball stuff might be, the emerging diseases, if there's some weird thing it might be but the veterinarian probably the first time is still not going to submit it. It might be the second or third death or oddball clinical exam that he sees where he's finally saying "I should submit this to try to figure out what's going on." (Interview 2, Lines 121-128)

The AVSN-VPS has made participants aware of the regional differences in infectious disease occurrence:

> I think the other thing that we fail to realize […] is how different geographically, even in Alberta, certain diseases are. […] I had no idea that *Clostridium hemolyticum* was more of an issue down there. We never had it in our area. In fact, when they told me that, how many cases they got, I thought they were just spoofing me […] Now you take across Canada and it's huge, […] just the different geographic areas and what diseases they see. (Interview 2, Lines 64-68)

Several participants described how surveillance influences the frequency of veterinary presence on farms, referencing the BSE surveillance program in particular:

> With BSE surveillance, […] financially we benefit, but… where it's really benefited I think is where we were able to go out to [farms]. In the past, a farmer loses one, […] a cow dies… He thinks it incidental, drags it in the bush and that's the end of it. When BSE hit they wanted samples from these specific ones and the ones that died were included in that. "A" we got out there to find out what's going on and I really felt that we learned a lot because "A" we could go

> out, diagnose a problem and in numerous cases we found issues. I mean whether guys were having a higher incidence of traumatic reticuloperitonitis and we could implement some sort of [control] or it was *Clostridium hemolyticum* and we could institute a vaccination program. We never would have had that opportunity before. It got us on the farm in a non-confrontational way. It didn't cost the guy so he was happy to have us out. He's getting paid. […] In some cases, okay, it's an incidental death, don't worry about it. He was happy because he could rest at ease but it really got us out into the [field]. In some cases, I hate to admit this in a way, but when BSE testing came about, some of our worst clients became our best from a financial standpoint because they were the poor managers in there, the ones that lost the cows and traded cows and bought cows and did all these things but at least we were able to figure out what was going on, on their place. We got in kind of behind the scenes and out at the pastures and we could see what was going on so it was a real benefit I thought. We never would have had that opportunity unless the guy lost three or four cows in a row. (Interview 2, Lines 235-236)

<u>Participants' perceptions of the role for government in surveillance</u>

On the subject of the role of government in surveillance, all participants advocated for further support for diagnostic laboratory-based surveillance from the government.

> I would really like to see the government come back and subsidize some more lab services and diagnostic services for food animals. I do think they need to provide a lab component to this surveillance system [AVSN-VPS] and I'm not sure how they're going to do that.
>
> The problem now of course is we've got no real good broad diagnostic services in the provincial government in Alberta. I mean all of our lab work gets sent out of province and so […] we pay more than the Saskatchewan residents to get the same work done.
>
> We've got the infrastructure in Alberta to set up labs to do a lot of this stuff and so if the government really wants to

> collect more and better data, then I think they should provide some support for lab work. (Interview 1, Line 63)

According to another participant:

> I think that you'd have to strengthen the diagnostic lab base and make it available. You have to make it non-cost prohibitive so that the producers are willing to get some of that done so that they don't have… a dead animal plus three or four hundred dollars in vet bills on top of that.
>
> From a government point of view, from an industry point of view, we have to have in place a lab network in order to detect some of these things that are going to come. (Interview 9, Lines 101-102)

Participants frequently drew attention to the costs borne by producers:

> I think that there's a big difference in the information that we want to receive and the economics borne by the producer. […] Right now the producer pays for the investigation, he pays for the test, then he may well pay for any adverse effects on his herd, his life or his livelihood that the results may show. […] We haven't got timely access to labs so we don't have timely access to information and again it's a producer pay situation. (Interview 9, Lines 139-141)

Several participants expressed the opinion that surveillance needs to be government driven and, in a number of instances, expressed frustration with the lack of attention and resources the government directs towards disease surveillance in the animal population:

> Government is so intent on cutting costs that they're putting their animals, their industries at risk and the cost associated with the risks are much higher than the costs associated with normal access. The billions of dollars lost with BSE is way higher than the cost of running some extra provincial government labs. […] Our government is looking at cutting costs and providing bare necessity services and moving costs onto individuals. The individuals do not have the ability to pay for the costs of testing and the government is short sighted by pushing those costs onto the

> individuals. Those things are going to create havoc in the industry when one of these things emerges because we do not have a proper surveillance network in place. We don't have a mandatory surveillance network in place. We don't have a proper lab system throughout the province that can handle these things in a timely fashion […] These things are coming. They talk about globalization, well globalization also means the occurrence of diseases that we would never have seen before whether it's human diseases like SARS or whether it's animal diseases like BSE but we have to improve and have to increase our lab availability so that those industries can be protected. (Interview 9, Lines 95-96)

When asked if clients talk about potential government involvement with the animal population and surveillance or disease outbreaks, one participant replied:

> No. Basically they [producers] just complain about BSE stuff, all the new restrictions and things like that. […] Nobody likes when the government gets involved, you know flat out, might as well say it… I don't even think they notice when I'm filling out a form, […] nobody's ever even asked what they are. (Interview 4, Lines 90-91)

The same participant then said the following about the BSE surveillance program in Alberta:

> I think part of the problem with the whole program is that it got to be in people's heads that it was out there for compensating the farmer as a culling program for animals that need to be taken out of the herd. They relied on it as a way to get compensation for these old lame skinny cows [..] They looked at it like the government doing them a favour. Then when all these restrictions came in, it was very hard to explain to people what the actual purpose of the program was and always has been [...] It did become a personal way of culling your old skinny lame cows and when it's not allowed anymore, they don't understand why and you're trying to explain to them that this isn't a culling program, this is actually a surveillance method for our country to be able to get points, saying we're surveilling for BSE and that we need to target a certain age population of animals in order to get good stats and good surveillance so

> we're not just out there to sample all of these random animals, they need to fall into a certain category. If [they qualify] then great, we want to give you some compensation but that was really hard for people to take […] That was really hard to get across to some people and like I said I'd go from doing dozens a month [BSE sample submissions] to like one every five or six months.
>
> Obviously, I understand how they want to make it appealing to the producer to participate and how they do that by money but I think the main purpose of the program was never brought to the forefront like it should have been and that made our jobs a lot harder when they put these restrictions in place because these people are yelling and cursing at us and you're just trying to explain what the whole point of it is. (Interview 4, Lines 92-100)

When asked if there would be some benefit to trying to communicate some of the goals of surveillance efforts, the reply from this participant was:

> Of course. Knowledge is power as the old cliché goes… The more that you introduce this idea to people and the general population and the producers, the more information they have about it, the more they understand. […] I think making them more publicly aware that we're out there, we're doing this for the benefit of our national herd, we're surveilling as well as for public health protection… the more accepting they probably will be of it, the more they'll understand and they won't be so concerned about why we come out and take samples. (Interview 4, Lines 101-102)

A number of participants discussed their perceptions of government. The Canadian Food Inspection Agency (CFIA) was not viewed favourably, though the provincial government fared better:

> I've always had a pretty good respect for the provincial veterinarians but what's really upped it is this AVSN [AVSN-VPS] I would say because there's that collaboration between the different levels. What's good about this thing here is that CFIA, the federal ones, […] I don't think we really see the collaboration with the federal [ones]. I mean there's always some government body that's

> ready to give us hell if we don't fill out forms properly but the provincial ones, there's a huge collaboration and I think a huge kind of respect that way. I mean we're looking after our little practice area. They're looking after the province… which is comprised of all these practice areas added in so you need that collaboration. (Interview 2, Lines 203-206)

One participant articulated dissatisfaction with the CFIA and its handling of reportable disease cases:

> For example reportable diseases that occur in the area the CFIA picks up, do you think we're notified first on the list that one of our clients might have a certain problem? No. We're usually one of the last people to find out and usually it's from the producer. I think that's pretty terrible […] Yeah there was one in our area from one of our clients and I knew nothing about it until he came in having all these questions about possible implications to his herd and slaughtering and all of this kind of stuff and I'm like "what are you talking about" and he was given very little information by them and I ended up having to phone the CFIA and chase someone down to talk to and get the story and find out what was going on. Something reportable is right here in our own backyard and we weren't even notified by them […] It was on a random screening sample at one of their plants and they picked it up […]
>
> I think in that sense, not only is that very poor relations but it sends a bad message to us because veterinarians are proactive type "A" people that want to be involved and if I'm going to go out […] and invest my time, my effort and I care about this and then you know I submit it and something comes back or you find something out about you know a herd in our area and then you don't even bother to contact me and let me know, I think it sends a really bad message out: "We don't want to work together. We don't want to involve you or help you" - so that makes it difficult too when they want us to do stuff for them or send a certain message. (Interview 4, Lines 137)

A few participants stressed the importance of communication:

> I think that they [producers] have to know what's going on regionally. […] If something actually does come up we will be able to get that information to them and it doesn't matter if it's in Medicine Hat or if it's in High River, if those things are being identified, then we'll be able to get that information to them and be able to use that information for prevention and treatment control, whatever has to be done. If information is not readily available and not disseminated, then these things can go on and on without any communication and that becomes an issue if we get it second or third hand. One, we don't look very good as veterinarians because we're not on top of our game and the other thing is that we may end up getting into disease situations that are preventable if we had prior knowledge.

<u>Participants' perceptions of the role of surveillance</u>

Many participants talked about surveillance and the greater good or its value beyond infectious disease event detection.

> I think these programs are worthwhile. Again, they change as government funding changes, as interest and direction changes from that end as well, but I believe they have value and that's why I got in [AVSN-VPS] at the start. (Interview 7, Lines 421-422)

Several participants discussed surveillance outputs to inform clinical practice and increase awareness of regional differences in infectious disease burden.

> I think that there is a really strong correlation in knowing what's going on and how well I do my job. I think that precisely if I know what's going on I can either treat it very effectively or say shoot that calf or shoot that cow or whatever. If I know what it is, you can fix it sometimes. If the producer knows, if the producer has confidence in my ability to fix something, he's going to see an economic benefit in having things fixed. (Interview 8, Lines 242-245)

One participant expressed the opinion that disease has not changed much over the past twenty years and pre-diagnostic disease surveillance programs do not help significantly in addressing infectious diseases, though such programs are great for the international reputation of the cattle industry in Alberta.

Participants cited frequently that surveillance benefits the cattle industry, though a few expressed frustrations that the producers are not deriving any benefit from increased surveillance:

> From that end I have been frustrated. With a variety of these programs is that again we've done a lot of hoops and it's just not changing this industry. It's in a sad state and yet they've [producers] connected the dots that have been asked of us but that being said, you can't say well let's just back it all up because there's no value in it. You just keep on plodding hoping that at some point it will be recognized for that. So that part I guess is the frustrating end of it. (Interview 7, Lines 365-367)

Participants also cited veterinarians, the industry, and the public as beneficiaries of surveillance. During a number of interviews surveillance for EIDs was mentioned in particular, with one participant expressing scepticism concerning the ability of the AVSN-VPS to provide information that might be missed by diagnostic laboratory-based surveillance:

> I don't think that they do that. They may in those cases in that they have a pathology team behind them. For those odd cases, those one percent or less of cases […], they will provide us with support there. Basically they're tracking the stuff that we would normally see so they're telling us occurrence of commonly associated diseases but they really aren't giving us an indication of new and emerging diseases and I don't think they're mutually exclusive because that's not how I see their mandate. Maybe it is if we see some of these and we don't know what it is so we end up phoning them and they get their lab people involved and we end up with a positive diagnosis. Maybe that's the way it will work but there are few veterinarians that are involved in that and

> this disease might be occurring […] where they're not part of the network so how can that possibly act as surveillance for those emerging diseases? (Interview 9, Lines 96-100)

Theme three: The veterinary perspective

There were two categories identified that relate to the veterinary perspective: 1) changes to the beef industry and the veterinary profession; and 2) cattle producers (Table 5.2).

<u>Changes to the beef industry and the veterinary profession</u>

All participants discussed the dynamic nature of the beef industry, the veterinary profession, and the relationship between the two. Economics were often drawn into the discussion. Emphasis was placed on the need for financial compensation to motivate changes to the beef industry:

> Unfortunately I think a lot of producers, they won't change unless they have to and there's two ways you can do that, you can force them to by saying that you have to put these tags in or you'll get fined or we can say you have to do it or you can't sell your product. I think probably the better way is you somehow make these subtle changes in the system that he has to do it. We're starting to do that anyway but the problem is you, if you're going to make those changes, you have to make it economical for the producer. If you're going to make him do a lot of extra stuff, then he has to be compensated for that. You can't continue to download […] a lot of work and paperwork and regulations on this producer and then expect him to do it and not be compensated. He'll just get out so I don't think that they're going really lead the change unless there is economic benefit to that. (Interview 3, Lines 260-262)

In many instances, participants highlighted that the role played by veterinarians has historically been different and is bound to continue to change:

> Yeah, it has to change [what veterinarians do]. I support my family by doing a lot of technical stuff, pulling calves, not so much anymore but pulling calves, pushing prolapses, preg[nancy] testing cows. […] I think the stuff […] about the connection between animal and human disease and looking at the big picture, that's incredibly important and that's going to be a sustainable aspect of our profession. I think it's unrealistic to think that […] the next generation veterinarians are going to do what I do. I showed you there's rings in the back of the clinic. You know that guy obviously made a living doing a thousand Caesarians in the spring. […] He made a significant portion of income by vaccinating heifers for brucellosis. I don't do that anymore and so why would I expect the next generation of veterinarians to do what I do for a living. I think that they have to look in their crystal ball, that's a hard thing to do, is what do we do as a profession to maintain our relevancy. (Interview 3, Lines 105-111)

One participant described how much the veterinary profession has changed during their career:

> I mean I've had herds that when I first started here in '94 that were losing ten or fifteen percent of their calf crop just with scours and through better management and better vaccine programs, we've reduced that to less than two percent. So absolutely we make them money. If I didn't think I was making my clients any money, I wouldn't do it […] We've gone past that though and historically that was true. If we had high feed costs, I save them money by getting rid of their cattle that weren't pregnant. […] Historically that was true because we could make some big changes but the changes we make now are small. Those people are already on vaccine programs […] When I started 30 years ago, it was an astronomical problem with bulls and Caesarians. We were doing two to three hundred Caesarians every fall in a 5,000 mother cow practice. Now in a 5,000 mother cow practice, we might do four or five Caesarians because we've improved the mother cows. We've improved the bulls. We've improved the feeding programs. We've improved the vaccine programs. We have much better antibiotics now than we had before. The changes we make now are much smaller […] It's much smaller [the gains that can be made] so for them to quit

> using veterinarians now doesn't make as big an impact as it did before.
>
> With us going away, they can still buy all their vaccines at UFA [United Farmers of Alberta]. We don't have any control of that like they do in Europe and other countries where they have to be bought through a veterinarian. A lot of that is reducing the amount of time that veterinarians are spending there too and maybe […] we're supposed to phase ourselves out. We're supposed to just now be fire engine veterinarians again. I mean these kids now are taking courses. They're learning it all. Some of these kids know more than we do, the kids of the ranches. They're being well educated right so we're not needed anymore for a lot of things other than the Caesarians and the dystocias and the bad things and the government programs. (Interview 6, Lines 172-197)

The same participant issued this prediction for veterinarians practising under similar circumstances:

> Nobody is going to be a cow veterinarian anymore. You can't hire kids to do this anymore. We're dinosaurs. We're done. Veterinarians that do everything are finished. These small practices are done. As soon as we die, they're done. They won't start again. It'll all be big practices. (Interview 6, Line 366)

<u>Cattle producers</u>

During all of the interviews the circumstances of producers was touched upon, and perceived to be as dynamic as those of veterinarians:

> I think they're in a similar position that we are, they have to change, they can't continue to raise cattle the way their grandfather did, just like we can't continue to practice veterinary medicine like three generations ago. Part of that education process is I can count on one hand young cow producers that want to produce cattle, the majority of guys are old or older. If you can target these young guys that are ambitious and want to do it, you have to convince them that

> they have to do it differently and that's part of the education process is "how can I help you do something different to be sustainable and make a living raising cattle instead of having to have two off-farm jobs to support the farm", and that's a challenge. (Interview 3, Lines 237-239)

Many participants expressed the view that producers fear a reportable or notifiable disease, though in contrast one participant expressed the following view:

> They would just love that, to find a disease in their herds where the government would buy their herd from them. That's how bad and how unhappy they are with the whole beef industry anyway. If they found BSE in somebody's herd, right on. Give me 2,000 dollars a piece for my cows and get rid of them. I don't want to do this anymore […] There's no money in it. It's a dead industry. (Interview 6, Lines 327-331)

In the opinion of a few participants this fear was in part attributable to producers fearing the stigma of being found with a reportable or notifiable disease:

> They understand that the chances of them having a positive is extremely low. What they're scared of is being in the spotlight and all of a sudden the neighbours, you know it's a bad stigma. If you're the guy in the community that's got a positive for something, you don't want to be the guy that's got a positive foot and mouth or a positive BSE or a positive anything - so I guess it's education on our part that it's sort of like, you know they tell people with cancer, the one thing worse than finding it is not finding it right? So you tell them that that if you don't find it now, that you're going to find it eventually. (Interview 3, Lines 220-223)

Some participants discussed the importance of independence to producers along with the concern that once current producers get out of cattle farming there will be no one willing to farm cattle in Alberta.

> The only reason you farm is a lifestyle. I shouldn't say the only reason. It's one of the biggest reasons that people farm. It's a great place to raise a family and you're outside, you're your own boss, nobody else telling you, you have to

> do this. I don’t have to get up today if I don’t want to or I can work all day if I want to or whatever you want to do, and that has appealed to most of the people that come from a rural environment and they want to come back to that. A big chunk of my clientele […] grew up on a family farm some place or here. They work in the oil patch to support their farm, and on their holidays, they come home and they make hay. Their kids resent the farm and they will not take over the farm. It’s because when holidays come and the city kids are off doing whatever else, out to the beach or holidaying, Dad’s home making hay. They don’t like that farm so the father who grew up feeling the farm was part of him and liked that, he comes back, can’t afford to farm but can live on a farm, have a bit of a hobby farm with oil patch industry and income. It dies with him. When he’s out of the game, there’s nobody taking it over and they’re a big chunk of who’s supplying the cattle right now in this MD [Municipal District in Alberta] (Interview 7, Lines 406-412)

Finally, a number of participants raised confidentiality and privacy as of concern to producers. In relation to surveillance initiatives and producers, one participant said:

> There’s a lot of less open minded people out that are very anti-government and there’s also just people that aren’t necessarily anti-government but that value privacy, you know that might have a concern with it remaining anonymous. I think if there’s a way that we could surveill more anonymously, that would be [ideal] and you know people are always more willing to accept that than if they have to put their name on something. For example, this [interview] right, if I’m going to talk to you about this and give you all these examples, I don’t want people to know I’m from {town name} or people will be like who in {town name} has this disease you know so I understand that from everybody right, nobody wants to be the one to have to stick a name to something necessarily. And some people are just very private and think whatever goes on, on my farm, is my business. (Interview 4, Lines 143-147)

Another participant expressed a slightly different view:

> I think most producers want these kind of [surveillance] programs. They want to know what the diseases are in their

> cattle and they want to participate in making our, or making their, product healthier and better and superior to other countries. […] I don't think there's anybody that really wants to hide anything. I think there's openness in most of these people, they're not afraid to share their information with anybody. At least not my clients. I don't see any problem. I mean they don't want us sharing it with all their neighbours, but with the government, that's alright. (Interview 6, Lines 157-162)

Discussion

In summary, the results pertaining to participants and diagnostic laboratories reveal a variety of drivers behind diagnostic laboratory submissions, with multiple animals affected and the impact of the results of laboratory testing on case management being common threads in a number of scenarios. Participants also stressed that the decision to submit samples depends on the management context as more disease is expected in poorly managed herds and vice versa. Participants detailed some of the benefits and limitations of diagnostic laboratory testing that also factor into their decision to submit samples to a laboratory. Economic realities, including the high cost of diagnostics relative to the decline in value of individual beef cattle, as well as a decline in government support for laboratory diagnostics, have contributed to a decreasing frequency of diagnostic laboratory submissions over time.

Participants expressed a willingness to participate in surveillance initiatives, though there is a need to support their involvement through monetary compensation and feedback of data and information that is relevant to clinical veterinary practice. Further, participants expressed the belief that veterinarians should take a more active role in surveillance.

Participants cited monetary compensation, information generated through surveillance activities, perceived value of the program, and additional laboratory support as reasons they had chosen to become involved in the AVSN-VPS and BSE surveillance programs. They cited information to inform diagnostic laboratory-based surveillance, greater numbers of submissions, and more timely information as gains from veterinary involvement in pre-diagnostic surveillance. Participants advocated for increased government involvement in surveillance and expressed the opinion that surveillance needs to be government driven, though efforts should be collaborative.

Participants highlighted a shifting beef industry, veterinary profession, and their interconnectedness, drawing attention to the economic aspects of the challenge this dynamic situation presents. Participants also provided a perspective on the position of producers that highlights: the need for producers to change the way in which they raise cattle in order to make a living; producers' attitudes and fears concerning the consequences of having a reportable or notifiable disease on their farm; and the value producers place on independence, confidentiality, and privacy.

Veterinarians and diagnostic laboratory submissions

Although participants recognized the benefits of laboratory testing, they also reported low submission rates and submission of fewer cases to diagnostic laboratories over time. The results show that diagnostic laboratory submissions from veterinarians are going to be biased toward: outbreaks; outbreaks with unusual mortality rates; atypical case presentations; bizarre cases; and cases with poor response to treatment or produce failure.

Therefore patterns detected by diagnostic laboratory testing are unlikely to reflect disease burden in the population. This finding is supported by quantitative studies looking at diagnostic laboratory test submissions (M. C. Thurmond et al., 1994; Zurbrigg, 2009). The patterns of diagnoses based on diagnostic laboratory findings should not be assumed to reflect disease trends in the general population. It may not be appropriate to rely solely on disease prevalence outputs reported by diagnostic laboratory-based surveillance to guide future research priorities.

It is interesting to note that while the circumstances of veterinarians in Sri Lanka described in Chapter 4 are different to those in Alberta, there were similarities in the challenges to diagnostic laboratory testing across contexts, namely the availability of sufficiently timely results to inform treatment and access to desired diagnostic laboratory infrastructure. The result in both contexts is that veterinarians have become accustomed to relying on other means to make a diagnosis and guide treatment. Changes to the veterinary diagnostic laboratory infrastructure in either Alberta or Sri Lanka that would significantly impact these challenges would require considerable investment and political will, and the time to realization of the benefits of such efforts would be lengthy.

One way of examining the diagnostic laboratory submission behaviour of participants is through the lens of expectancy theory from the field of sociology. Expectancy theory is concerned with the process individuals go through in arriving at the decision to perform one behaviour over another or others (Fudge & Schlacter, 1999; Liccione, 2007). At its foundation is the idea that individuals decide to act in certain ways because they are motivated to select particular behaviours out of a range of possible behaviours due to the results they expect to stem from them. There are three components of expectancy theory: expectancy, instrumentality, and valence (Fudge & Schlacter, 1999; Liccione, 2007). These three components play an interactive role in motivation. A large part of expectancy theory is what individuals perceive: individuals' actions will not be motivated by what the results will be, but by what they *believe* the results will be. One of the primary goals of veterinarians in private clinical cattle practice is to achieve positive case outcomes for their clients. Application of expectancy theory in this context reveals that if a veterinarian perceives a strong correlation between performing diagnostic laboratory testing and case outcome then instrumentality (an individual's belief that the rewards acquired as the result of an action are closely related to level of performance) will be high and the veterinarian will be motivated to pursue laboratory diagnostics. This theory helps to explain why diagnostic laboratory testing that does not inform treatment is often viewed as 'academic'. However, participants also cited suspicion of a reportable or notifiable disease or concern for a public health risk as case characteristics that encourage sample submission. In these instances the goal may be to confirm the absence of a reportable or notifiable disease or a public health risk. Though based on past experience the likelihood of a reportable or notifiable disease or public health risk is low, the valence (the degree to which an individual values a particular award) attached to identifying either event is high. There are theories from other fields that are concerned with peoples' expectations for the future, including the rational expectations theory from economics (Muth, 1961). This theory is based on the hypothesis that while individuals' expectations are wrong at an individual level, they are correct on average. There is a large body of literature that deals with the implications of this assumption (e.g., Lucas, 1990).

The results show that participants' perceptions of the limitations of diagnostic laboratory testing and economic considerations related to diagnostic laboratory submissions have changed over time to depress the motivation of participants to submit cases to diagnostic laboratories. In particular, the time lag between when samples are submitted and when results are available has lengthened as the diagnostic laboratory infrastructure in Alberta has changed. Additionally, the decline in value of cattle and in government support for diagnostic laboratory testing means that the financial burden of diagnostic laboratory testing borne by producers may be too great a cost compared to the perceived benefits diagnostic laboratory testing provides.

Participants reported they are getting onto farms less and less, presenting fewer opportunities to even consider submission of diagnostic laboratory samples as an option. This change to the presence of veterinarians on farms translates into fewer opportunities for veterinarians to experience the benefits of diagnostic laboratory submissions and is likely to have the greatest impact on recently graduated veterinarians for whom diagnostic laboratory testing facilitates learning and builds confidence.

There are strengths and limitations to relying on diagnostic laboratory submissions from cattle veterinarians in Alberta for EID event detection. EID events characterized by atypical case presentations or bizarre cases are likely to make it to the level of the diagnostic laboratory, though participants reported that it would be unlikely for the index case to be submitted. Submission to diagnostic laboratories would also necessitate veterinarians to recognize that some number of cases over time are sufficiently similar to have an underlying etiology. The ordered diagnostic laboratory test would have to be capable of detecting the agent or, in the event that histopathology or cytopathology is the test ordered, the pathologist would need to recognize that the case represents something out of the ordinary (Chapter 1, Figure 1.3). Participants also indicated that samples are submitted when there are unusual outbreaks or in situations where there are large numbers of animals affected. Surveillance of diagnostic laboratory submissions may therefore be sufficient for detection of EID events characterized by these types of presentations, though it is difficult to determine if detection would be sufficiently prompt to mitigate their impact on animal and public health. In contrast, given the overall small number of sample submissions reported by participants, diagnostic laboratory-based surveillance is unlikely to detect slower-moving EID events that present more sporadically or changes in trends of known endemic problems as incomplete sampling is unlikely to generate a signal in the diagnostic laboratory data stream (Wagner et al., 2001).

The AVSN is part of the Canadian Animal Health Surveillance Network (CAHSN), a network of provincial, federal, university, and private animal health diagnostic laboratories (Kloeze, Mukhi, Kitching, Lees, & Alexandersen, 2010). This newly established network aims to: 1) increase diagnostic laboratory capacity to detect infectious animal diseases; 2) permit implementation of common protocols, including use of common reagents; 3) coordinate surveillance activities; 4) enable the sharing of technical and scientific expertise; and 5) enable collation and analysis of laboratory data from participating diagnostic laboratories (Kloeze et al., 2010). The objective of the CAHSN is "early detection of animal disease threats to the food supply, food safety or public health originating through bio-terrorism or 'natural' causes, especially foreign and emerging animal diseases" (Kloeze et al., 2010). While this integration effort helps to ensure there is sufficient diagnostic laboratory capacity in place to respond to EID events, and detect certain types of EID events, the results reported here suggest that such efforts alone will be insufficient to permit early detection of animal disease threats: diagnostic laboratory submission results are unlikely to signal the occurrence of an EID event in the animal population early in the epidemic process (Wagner et al., 2001).

Veterinarians and surveillance

Surveillance is a function of public health services that is undertaken by people in a wide range of contexts: the practice of surveillance is directly related to the environment in which it takes place and therefore a socio-ecological approach to analysis is warranted in this chapter. There are a number of variations of the socio-ecological model that have been developed based on the work by Bronfenbrenner, 1979. They all identify levels of influence on human behaviour that overlap and taken together comprise the environment in which human behaviours take place. An assumption inherent to the socio-ecological approach generally is that assessment and approaches to intervention that operate at multiple levels are more effective in comparison to those that operate on a single level (L. W. Green, Richard, & Potvin, 1996). For the purpose of this chapter, five levels of influence will be individually explored (individual, interpersonal, organizational, community, and societal) that are widely utilized when adopting a socio-ecological approach (Bronfenbrenner, 1979).

Individual-level influences on surveillance

The individual level in the socio-ecological model emphasizes the importance of characteristics of the individual to intervention strategies. Veterinarians in Alberta that provide animal health care services to the cattle population are part of a private industry and therefore some form of compensation for time dedicated to surveillance initiatives is essential. However, animal health surveillance is not the only duty of these veterinarians: the results of this study show that while monetary compensation is important, it is not sufficient to guarantee participation of veterinarians in surveillance. Participants emphasized that surveillance that relies on private clinical veterinarians to input data needs to generate information that is of value to veterinary clinical practice. One challenge to animal health surveillance programs is that they need to serve the interests and needs of a number of stakeholders including governments, consumers, industry stakeholders, and producers (Del Rocio Amezcua et al., 2010). Surveillance that is dependent upon veterinarians in private practice to submit data has the additional responsibility to provide data submitters with information that is clinically relevant (Del Rocio Amezcua et al., 2010). Future surveillance initiatives and modifications to existing programs must take this task into account during design, implementation, and evaluation to help ensure surveillance system sustainability.

Interpersonal-level influences on surveillance

The interpersonal level in the socio-ecological model emphasizes the importance of social norms and social influences to intervention strategies. Veterinarians have an ethical duty to promote public health defined in the veterinarian's oath (Babcock, Marsh, J. Lin, & Scott, 2008). Participants expressed a willingness to contribute to pre-diagnostic surveillance initiatives, the belief that veterinarians should take a more active role in surveillance, and the opinion that government needs to deliver surveillance programs. However, the results show that this approach needs to be one of collaboration and must take into account the relationship between producers and veterinarians. The success of private veterinarians is dependent upon their relationship with producers: it is imperative that surveillance initiatives reliant on the participation of private veterinarians respect this relationship and not serve to undermine it. For example, pre-diagnostic surveillance initiatives may need to include mechanisms that ensure specific farm locations are excluded from case submissions in order to protect the privacy of producers and gain support from veterinarians, as was done with the AVSN (John Berezowski, personal communication). In addition, the goals of surveillance initiatives need to be communicated to producers so that when changes are made that are deemed necessary producers understand the reasons behind them. An even better approach would be to include producers in the process of negotiating changes to existing surveillance initiatives so their comments and perspective are considered and they are not caught off guard when changes are made.

While it is common practice to calculate the economic consequences of EIDs (Newcomb, 2003) and investigate their impact more broadly (Rushton & Upton, 2006), projecting the economic benefits realized through surveillance remains a challenge (Elbakidze & McCarl, 2006). It is also impossible to pinpoint EID events that have been averted as a result of surveillance. The BSE surveillance program in Alberta that requires veterinarians to visit cattle operations to collect brain stem samples has had both direct and indirect consequences to the veterinary perspective on the cattle health situation. While it serves to satisfy many consumers and trading partners that the prevalence of BSE in Canada's cattle population is very low, and the risk of a BSE-positive cow entering the food chain is very small, the results show that it also translates into more veterinary contact with the cattle population, in particular with segments of the population that previously had minimal contact with the veterinary profession. This increased contact could prove essential to recognition of future EID events. Creating circumstances for veterinarians to get onto cattle operations in the absence of a major problem, or in a 'non-confrontational way', has the added benefit of improving the relationship between veterinarians and producers. This enhanced affiliation could prove invaluable during future EID events as producers would be more likely to bring animal health concerns to the attention of their veterinarian, creating more opportunities for event recognition, thereby enabling more timely EID event detection and response.

Organizational-level influences on surveillance

The organizational level in the socio-ecological model recognizes that changing the policies and practices of a workplace can serve to support behavioural change. In Alberta, providing the ARD with additional resources to support the activities of cattle veterinarians, in particular further diagnostic laboratory capacity, is an incentive for surveillance system participation that was identified by participants as essential. As suggested by one participant, collaboration on a list or decision tree that would inform diagnostic laboratory testing supported by the government is one approach to future diagnostic laboratory-based surveillance by the ARD that remains unexplored. This type of approach could be particularly useful as it would enable targeted case presentations to reach the level of the diagnostic laboratory and it would heighten awareness to these case presentations among veterinarians. Efforts to communicate with farmers about such programs would help to ensure cases are being brought to the attention of cattle veterinarians.

Community-level influences on surveillance

The community level in the socio-ecological model recognizes that coordinating the efforts of members of a community, in this case cattle veterinarians in Alberta, is necessary to bring about change. The results presented in this chapter demonstrate how the AVSN-VPS has served to provide cattle veterinarians in Alberta with a shared perspective on the burden of clinical disease in Alberta's cattle population, an essential first step in bringing together members of a community (Baker & Ross, 1996; Ndiaye et al., 2003). However, the results also indicate that the information produced from the AVSN-VPS has limited applications in cattle veterinary practice. Administrators of the AVSN-VPS should consider consulting with veterinarians who input data to determine how to make the information provided more relevant to data providers, and if any further data types might be worth collecting. This consultation process would also serve to enhance the collaboration between the AVSN and cattle veterinary practitioners.

Societal-level influences on surveillance

The societal level in the socio-ecological model recognizes that there are societal or cultural high-level factors that create a climate that encourages or discourages behaviours. Broadly speaking, governments and the public health community create a climate that impacts willingness to report EID events. This process is operating at the level of nations, veterinarians, animal health care workers, and producers. Surveillance programs can serve to improve the relationship between veterinarians and government regulatory bodies (Baker & Ross, 1996). The AVSN-VPS has generated information concerning the perspective veterinary practitioners have on health-related events in the cattle population. This information is shared between private practitioners and veterinarians at the ARD and creates a knowledge base around which to dialogue. Participants highlighted opportunities to enhance this relationship, in particular the need for diagnostic laboratory support guided by the outputs of the AVSN-VPS. The needs of consumers, producers, veterinarians, and the provincial and federal government could be well served were the ARD to utilize the willingness of veterinarians to participate in surveillance and participants' recognition of the need for change within the veterinary profession. A collaborative effort between private veterinarians and veterinarians at the ARD to develop a government-supported diagnostic laboratory surveillance program that satisfied veterinarians' desire for further diagnostic laboratory support, the requirement of the provincial and federal government to surveill for and report potential EIDs events as part of Canada's membership in the OIE, and the public's need to be assured of a safe food supply could enhance the relationship between private veterinary practitioners and the ARD. This type of endeavour could be invaluable during future EID events as control of past events has required cooperation among producers, veterinarians and multiple government agencies (Scudamore & Harris, 2002). The CFIA should explore means of improving their relationship with private cattle veterinarians as they are integral to detection of outbreaks of OIE listed diseases and evidence of a healthy working relationship between the two parties from the perspective of participants was lacking.

The veterinary perspective

The results of this study suggest that the beef industry and the cattle veterinary profession in Alberta are going through a period of significant change, and that the two are strongly linked. Previously, cattle veterinarians had an important role in performing technical procedures such as caesareans to treat animal disease conditions. They also had a role in implementing management programs that have decreased the burden of animal health conditions requiring veterinary intervention. Producers have learned alongside veterinarians and no longer require veterinarians to perform all the functions they did previously. Participants in this study identified this phenomenon and the need for the veterinary profession to change in response, though there were differences between participants in what those changes might need to be. From an EID standpoint, one avenue the cattle veterinary profession might consider exploring is increasing its emphasis on healthy animal populations, as opposed to animal populations that are simply free from disease: healthy animals are more resistant to infectious diseases (Coop & Kyriazakis, 2001; Field, Johnson, & Schley, 2002) and could serve to help mitigate the risk of future EID events in animal populations. If the model of private veterinary services to food-producing animals is going to persist, changes to the services provided by the veterinary profession are going to have to be economically relevant to producers.

Participants perceived that farming has historically attracted individuals that value independence and privacy. As a result there is inherent potential for conflict between producers and the need for improved government-driven EID surveillance. Future surveillance initiatives will need to consider this aspect of cattle production to encourage producer involvement and to help build an industry that attracts a future generation of farmers. Participants also highlighted that challenges to the beef industry in Alberta have made raising beef cattle less economically viable and that BSE in Canada has placed producers under considerable strain: producers fear not only a reportable or notifiable disease but the stigma that would come along with being ‘the guy in the community that’s got a positive’. Participants believed that producers are bearing much of the cost of surveillance and have yet to realize the benefits of surveillance programs initiated in part in response to the BSE crisis. These circumstances remain an ongoing challenge to surveillance: the negative consequences of an EID or reportable or notifiable disease are more tangible than the purported benefits associated with robust surveillance initiatives (Rushton & Upton, 2006). As surveillance serves the interests of producers, the food-producing industry, consumers, and the public (Umali et al., 1994), distributing the economic burden of surveillance among these parties is warranted. Though the cost of pathogen surveillance in animals is already distributed among these parties, the opinion expressed by participants suggests that further study is needed to ensure cost sharing is equitable.

The economic impact of delayed detection of future epidemics could be tremendous (Carpenter, O'Brien, Hagerman, & McCarl, 2011; Kaufmann, Meltzer, & Schmid, 1997). Though the damage caused by delayed detection has been clearly demonstrated through retrospective analysis of previous outbreaks (Newcomb, 2003), these observations have been insufficient to motivate a global effort sufficient for early EID event detection and response (Daszak, 2009). A component of this issue is the relative lack of attention that has been paid to the social elements of EID surveillance. In order to be more effective, future surveillance initiatives need to incorporate an enhanced understanding of the human dimension of surveillance to encourage people closest to EID events to recognize, report, and respond.

Table 5.1: Open-ended questions and follow-up probes used during veterinarian in-depth interviews

Discussion topic	Key question and follow-up probes
Decision making around diagnostic laboratory submissions	Please describe the various factors that affect your decision to submit samples for laboratory diagnostics. • What do you see as the benefits of laboratory confirmation? • What are the costs, in addition to monetary, of sample submission? • Are there instances where laboratory testing is more warranted – or less warranted? • When it comes to sample submission, who is the primary decision maker in the process • What kind of value does laboratory testing provide? • Are there types of cases in which you feel laboratory testing is more urgent? • Do you have particular ‘flags’, ‘indicators’, or scenarios that prompt you to consider laboratory testing more carefully?
Participation in disease monitoring and surveillance	Please talk to me about how willing you think veterinarians are or would be to participate in a disease monitoring and surveillance program. • Why have you chosen to participate in the AVSN? • What are the obstacles to participation? • What are the potential benefits to participation? • Is there conflict between the different roles veterinarians are supposed to play and the interests they are compelled to adhere to or represent? • How could veterinarians be better engaged in disease monitoring and surveillance? • Do you think veterinarians have additional information to provide that may be missed by diagnostic laboratory based disease monitoring and surveillance?
Disease monitoring and surveillance and client interactions	Do you discuss disease monitoring and surveillance with your clients? • Please talk to me about the range of attitudes you encounter, using specific examples wherever possible. • How do you address concerns clients have about the consequences of infectious disease identification? • What do you see as the potential benefits to such conversations? • What do clients see as their role in disease monitoring and surveillance or do they see themselves as having a role at all? • How concerned about the potential for disease outbreaks do they appear? • How do you think clients could be better engaged in disease monitoring and surveillance?

Table 5.2: Research aims linked to the themes and categories that emerged during data analysis

Research aims	Themes	Categories
To advance understanding of the factors that influence cattle veterinarians in mixed-animal and cattle private veterinary practice in Alberta to submit cases to a diagnostic laboratory	Veterinarians and diagnostic laboratory submissions	Drivers of diagnostic laboratory submissions Benefits realized through diagnostic laboratory testing Limitations of diagnostic laboratory testing Economic considerations related to diagnostic laboratory submissions Characteristics of diagnostic laboratory submissions
To describe the complex of factors that affect the willingness of cattle veterinarians in mixed-animal and cattle private veterinary practice in Alberta to participate pre-diagnostic surveillance programs	Veterinarians and surveillance	Willingness to participate in surveillance initiatives Veterinarians ought to participate in surveillance Drivers for involvement in surveillance initiatives Gains from the involvement of veterinarians in surveillance Participants' perception of the role for government in surveillance Participants' perceptions of the role of surveillance
	The veterinary perspective	Changes to the beef industry and the veterinary profession Cattle producers

CHAPTER 6: CONCLUSIONS

Introduction

The global public health community continues to be caught off guard by EID events in part because surveillance efforts have failed to focus on high-risk settings: namely lower-latitude, lower resource countries (Daszak, 2009). In addition, though the majority of EIDs are zoonotic (Christou, 2011; Jones et al., 2008; Taylor et al., 2001) and early detection of EID events in animals is postulated to reduce their public health impact (WHO, 2006b), little attention has been paid to how best to structure a surveillance system that uses animals as sentinels for EID events (Vrbova et al., 2010). Finally, despite the importance of human behaviours and decisions that determine what surveillance "sees" (Dorea et al., 2011b), little attention has been paid to this human dimension of surveillance. The goal of the work described in this thesis was to improve understanding of how to engage people on the frontline of EID event detection in order to collect a suite of animal health data that could enable improved situational awareness of EID risks. I addressed this goal by: 1) designing and field testing the IDSAS, a mobile phone-based pre-diagnostic surveillance program that allowed FVSs in Sri Lanka to rapidly report animal health information; 2) developing an assessment framework informed by published literature that better reflects the goals of using animals as sentinels for EID risks to humans; 3) applying the assessment framework to the IDSAS in the context of ongoing diagnostic laboratory-based surveillance in Sri Lanka to determine if the IDSAS has the potential to aid in EID early warning in Sri Lanka; 4) characterizing the attitudes and practices inherent to the decision-making process that veterinarians in Sri Lanka and Alberta go through when they approach clinical cases and determine whether diagnostic laboratory testing is warranted; and 5) investigating the motivators, disincentives, and attitudes of veterinarians in Sri Lanka and Alberta towards participating in pre-diagnostic infectious disease surveillance initiatives.

Contributions of this research

This dissertation addresses many questions about the potential role for veterinarians in reporting health-related events in the animal population that could enhance capacity for early warning of EID events of human health significance. The research contained here provides an example of implementation of a mobile phone-based surveillance system, the IDSAS, to generate information on the domestic animal population in a lower resource setting (Chapter 2). This is the first published attempt to use mobile phone technology and adapt surveillance methodologies from the human health field in order to collect data regarding encounters between the domestic animal population and veterinarians in a lower-resource setting. This work builds on a trend in surveillance to capture novel data sources with the aim of achieving more timely EID event detection. This is the only published study of this nature that has taken place in Sri Lanka. The EID intelligence framework provided a means of determining if the IDSAS made available information on animal health-related events that may help to forecast an EID health risk to humans (Chapter 3). This framework is the first of its kind. While intelligence is talked about in conjunction with infectious disease surveillance in the literature (Kaiser et al., 2006; Paquet et al., 2006), I could not find any publications that attempted to identify system attributes that are consistent with the goals of early warning and quality surveillance. No other research was found where people field tested an assessment framework that is consistent with animal sentinel surveillance. The framework also illuminated some of the strengths and deficits of the IDSAS and the ongoing animal diagnostic laboratory-based surveillance efforts in Sri Lanka and thus had practical utility in Sri Lanka. (Chapter 3). Note that the country has undergone a veterinary services evaluation and policy review, both of which recognized the need for enhanced surveillance and situational awareness (Dissanayake, Stephen, Daniel, & Abeynayake, In press). Two focused ethnographic studies with veterinarians in Sri Lanka and Alberta highlighted some of the biases in diagnostic laboratory-based surveillance data introduced by veterinarians who in part determine which domestic animal cases make it to the level of the diagnostic laboratory in these two different contexts (Chapters 4 and 5). These studies will serve to inform future thinking and research into the strengths and limitations of diagnostic laboratory data for detection of EID events in the domestic animal population of human health significance. Finally, these two qualitative studies also explored the factors that motivate and encourage veterinarians in Sri Lanka and Alberta to participate in pre-diagnostic surveillance initiatives (Chapters 4 and 5). No one has published qualitative studies that explore the factors that motivate or deter veterinarians to submit samples to diagnostic laboratories or participate in pre-diagnostic surveillance initiatives. These studies provide important insights that will inform future strategies for engaging veterinary practitioners and encouraging their participation in EID surveillance. They also complement existing literature on EID early warning that has primarily focussed on utilization of technological advancement for surveillance and development of data analysis methodologies. These studies will inform future surveillance systems that necessitate participation of frontline animal health care workers to generate information, including future initiatives that also learn from the experience described in Chapter 2.

The public health community is calling for surveillance that includes pre-diagnostic animal data for the purpose of early detection of EID events of significance to human health (WHO, 2006b). The response to this call has been a proliferation of surveillance systems that collect animal data. However, the vast majority of preliminary efforts have occurred in the continents of Australia and Oceania, Europe, and North America in high-resource countries (Dorea et al., 2011b; Vrbova et al., 2010). In contrast, the risk of future EID events is highest in tropical Central and South America, Asia, and Africa, where many countries have marked resource constraints. (Jones et al., 2008). Therefore, as a first step in addressing the disparity between where pre-diagnostic animal surveillance systems are being trialed and where the risk of future EID events is highest, I designed and implemented the IDSAS, a mobile phone-based infectious disease surveillance system used to collect animal health data from FVSs in Sri Lanka. In Chapter 2, I demonstrate that mobile phone technology can be utilized in the low-resource context of Sri Lanka for collection of animal health-related surveillance data. Evaluation is essential to maintaining support for surveillance programs in both animal and human health (German et al., 2001). However, little attention has been paid to the notion that because animal EID surveillance systems differ in their aims and objectives compared to systems intended to surveill for endemic and non-infectious diseases in human populations, animal EID surveillance systems may require different design and evaluation criteria that better reflect their aims and objectives, especially if they are to be used to forecast or quickly detect a change in public health risk. In Chapter 3, I propose a framework for EID intelligence informed by primary research and literature from the fields of surveillance, epidemic intelligence, and military intelligence that supports a goal of early risk detection in the animal population. Based on this framework I was able to show that the IDSAS met the following criteria for EID intelligence: timely; regular; reliable; acceptable; understandable; meaningful; interpretable; adaptable; detailed information on individual cases; supplemented the diagnostic hierarchy; documented other health-related events; provided case location data; inventoried historical trends on syndromes and endemic disease; and collected and integrated local knowledge from FVSs. While application of this framework cannot validate the predictive value of the IDSAS or any other surveillance system, it supports the conclusion that the IDSAS is a feasible and acceptable system with utility for frontline animal health data collection. The EID intelligence framework also aided in coherent organization of surveillance system attributes and helped to highlight strengths and weaknesses of the IDSAS, suggesting that the framework has practical value for surveillance system evaluation.

Surveillance of diagnostic laboratory case submissions is a component of many EID surveillance systems (Guerra, Walker, & Kitron, 2001; Kloeze et al., 2010; Krause et al., 2007; Shaffer et al., 2007). In order for a clinical case in animals to move from the field level to the level of the diagnostic laboratory there is a series of human judgements that must take place, involving primarily owners and veterinarians in the domestic animal health field (Tataryn et al., 2007). A recent review of the literature found that most pre-diagnostic surveillance methodologies rely on people, in particular veterinarians, to generate data (Dorea et al., 2011b). This is because people are either directly involved as data submitters with pre-diagnostic surveillance initiatives or analysis is focused on data generated through the activities of frontline animal health care workers, including case submissions for diagnostic laboratory testing and animal observations made during job-related activities (Dorea et al., 2011b). One of the lessons that can be learned from surveillance in the human health field is that participants in surveillance initiatives must be motivated and engaged if programs are to be successful (Chauvin & Valleron, 1998; de Stampa et al., 2009; Hummers-Pradier et al., 2008). In Chapters 4 and 5, I employed qualitative methods to explore the human dimensions of disease surveillance. I conducted in-depth interviews with veterinarians in Alberta and Sri Lanka to explore the decision-making process veterinarians go through in these different contexts when arriving at the decision to submit an animal case to a diagnostic laboratory and the relationship between veterinarians and surveillance.

In Chapter 4, I confirm the infrequency of diagnostic laboratory case submissions in Sri Lanka quantitatively detailed in Chapter 3. I report the absence of a describable case submission pattern among participants and detail the factors that explain the infrequency of case submission to diagnostic laboratories that occur at the level of farmers, FVSs, and veterinary services and infrastructure in Sri Lanka. These factors function as obstacles to regular and frequent submission of samples for etiological testing at diagnostic laboratories. Though it is impossible to generalize the findings around factors at the level of farmers and FVSs to other low-resouce settings, many of the deficiencies in veterinary services and infrastructure identified by the participants are similar to those cited in other publications that investigate public health care systems in other low-resource settings (Kruk, 2008; Petti et al., 2006). This finding is of importance if submission and disease patterns reported by diagnostic laboratories are relied upon to detect a change in clinical disease burden in the domestic animal population. The FVSs interviewed were focused on the treatment most appropriate given the animal clinical case presentation, as opposed to whether the clinical presentation represents something out of the ordinary at the level of the population. These findings suggest that patterns in sample submissions and diagnoses detected by animal diagnostic laboratories in Sri Lanka are biased by the selection process veterinarians go through as they determine which cases will be submitted to a diagnostic laboratory. This finding may preclude the use of diagnostic laboratory submissions as the sole data source in animal EID early warning surveillance initiatives in Sri Lanka. Upgrades to animal diagnostic laboratory capacity in Sri Lanka will not serve to address these human elements that ultimately determine which animal cases reach the level of the diagnostic laboratory. While there is a body of literature that emphasizes investment in diagnostic laboratory infrastructure in low-resource settings for EID early warning (Institute of Medicine and National Research Council, 2008; Keusch et al., 2009; Lemon et al., 2007; Petti et al., 2006), this strategy on its own would fail to account for the potentially significant biases arising from the role of veterinarians as diagnostic laboratory submission decision makers. The findings from Chapter 4, in addition to the results from Chapter 3, demonstrate the need for surveillance methods that include data beyond that collected by diagnostic laboratories to achieve EID early warning in Sri Lanka.

In Chapter 4, I also document FVSs' perceptions of the role and value of surveillance, their perceived limitations of current surveillance methodologies, their willingness to participate in surveillance initiatives, and the challenges to surveillance methodologies that rely upon FVSs to submit pre-diagnostic data. Taken together the findings indicate that strengthening existing networks of collaboration and communication that include FVSs, VIOs, and surveillance program administrators as an intervention strategy to improve EID surveillance in Sri Lanka would be particularly effective as it would operate at multiple levels in the socio-ecological model. The results also highlight the deficiencies in transportation and infrastructure in Sri Lanka that represent a significant barrier encountered by FVSs in their daily activities.

In Chapter 5, I found that cattle veterinarians in Alberta also infrequently submit cases to diagnostic laboratories. In contrast to FVSs in Sri Lanka, the cattle veterinarians in Alberta I interviewed had a diagnostic laboratory case selection process that is biased toward: outbreaks; outbreaks with unusual mortality rates; atypical case presentations; bizarre cases; and cases where there was a poor response to treatment or produce failure. This case selection bias may benefit detection of EID events that present with these clinical case characteristics. It is of concern that while significant effort is being put into the CAHSN that emphasizes the use of laboratory data in early detection of animal disease threats, limitations of diagnostic laboratory testing and economic considerations related to diagnostic laboratory submissions in cattle are concurrently depressing the motivation of veterinarians to submit cases to diagnostic laboratories. Additionally, these veterinarians reported getting onto farms less and less, presenting fewer opportunities for diagnostic laboratory case submission. Efforts that focus on improving diagnostic laboratory services available to veterinarians and networking of diagnostic laboratory infrastructure fail to more broadly address the factors dissuading cattle veterinarians from submitting cases to diagnostic laboratories.

The Alberta veterinarians interviewed were willing to participate in surveillance initiatives. Furthermore, they believed that veterinarians should be more actively involved in surveillance. Discussion of the drivers for involvement in surveillance emphasized monetary compensation and information generated and fed back through the program, though the former in isolation does not serve to motivate participation. This is consistent with what has been found in the human public health field (de Stampa et al., 2009; Hummers-Pradier et al., 2008). The interviewed cattle veterinarians believed there are gains to be made through their involvement in surveillance initiatives that go beyond understanding disease trends and identifying outbreaks, including improved marketing of animal products, increased frequency of veterinary presence on farms, and improved relations between veterinarians and cattle producers. The latter two benefits could have considerable impact in detection and response to future EID events as there would be more opportunities for veterinarians to notice a change in the burden of disease in the cattle population and cattle producers would be more likely to bring animal health concerns to the attention of their veterinarian. Literature examining the motivation of volunteers has found that people who volunteer bring with them their ideas and expectations about what they hope to gain from the experience (Henderson, 1981). If what veterinarians expect to gain through surveillance is in part motivating them to participate in various initiatives then ongoing participation could be encouraged by demonstrating to participants how programs are helping to achieve these gains, or informing participants about what can be realistically achieved through surveillance. The veterinarians that participated in this study also saw a need for governments to provide more support for diagnostic laboratory-based surveillance and take more of a role in disease surveillance in the cattle population.

In Chapter 5 participants highlighted the strong connection between changes in the beef industry and the cattle veterinary profession. From an EID event detection standpoint, the decreased utilization of veterinary services by the cattle industry is of some concern as methods that rely on veterinarians to input pre-diagnostic case data and methods that target submissions by veterinarians to diagnostic laboratories depend on producers to seek veterinary services in the event of clinical disease in cattle. The veterinary profession is going to have to respond to changes to the beef industry in order to continue providing services that are of significance to cattle producers. Study veterinarians expressed the view that farming has historically attracted individuals to whom independence and privacy is of value. This contributes to the potential for conflict between governments and cattle producers if future government-driven surveillance initiatives are perceived to encroach upon producers' independence or privacy. Cattle veterinarians reported that producers are under considerable strain from challenges to the beef industry that are making the raising of beef cattle less economically viable and fears of the consequences of future EID events. Taken together, these factors do not bode well for the future of Alberta's beef industry: there are few incentives to remain in the beef industry and fewer still to become a beef cattle farmer. Lastly, this work documents the need for public health agencies to understand the context of animal EID surveillance. The motivators and disincentives among veterinarians for tracking disease on farms for the purpose of public health protection are different than those of general practitioners in the human health field asked to perform a service to ensure public health (de Stampa et al., 2009; Hummers-Pradier et al., 2008). On farms there are layers of people (farmers and veterinarians) with layers of needs (independence, lifestyle, confidentiality, privacy, income, public health protection) and simply requesting animal data for the sake of the public good is unlikely to be an effective strategy.

Limitations of the experience in Sri Lanka

One of the primary limitations of this study is that lessons learned in Sri Lanka may not be applicable to other low-resource contexts. Work in the global health field has demonstrated the importance of national context during implementation of public health initiatives (WHO Maximizing Positive Synergies Collaborative Group et al., 2009). The delivery of veterinary services in Sri Lanka is somewhat unique as much of it is done through the public sector. Utilization of pre-diagnostic surveillance methodologies requires robust communications systems (Randrianasolo et al., 2010). Fortunately mobile phone technology is very available and accessible in the majority of low-resource contexts (Chretien et al., 2008). Surveillance system efforts in other countries that draw on the IDSAS experience need to take regional differences in delivery of animal health services into account during the design and implementation phases. In settings where veterinarians are not the primary providers of animal health services, other types of animal health care workers will need to be recruited as data providers. One example of such a setting is Laos in which there are few veterinarians and no national veterinary curriculum (Veterinarians Without Borders, 2011). In addition, garnering support at a variety of levels of government was critical to the success of the IDSAS. This has been shown to be relevant to health care initiatives that exploit mobile technology in a variety of low-resource countries (Vital Wave Consulting, 2009). In settings where veterinarians work primarily in the private sector different avenues for gaining support may need to be explored. One example might include professional organizations or cooperatives of livestock producers.

Sustainability of surveillance systems

The contents of this thesis highlight the need for further discussion of the issue of surveillance system sustainability. The findings from Chapters 2 and 3 regarding sustainability and the potential role for mobile communication are consistent with conclusions drawn in the human health field. Chapter 2 clearly illustrates that implementation and uptake of a surveillance initiative that utilizes mobile phone technology takes close to a year. Also in the majority of low-resource settings no comparable data set to that generated by the IDSAS exists and therefore it takes the minimum of a year to even establish baseline levels of data submissions that reflect seasonal patterns in syndrome and clinical disease occurrence. To address this challenge efforts are underway to develop statistical methods for detection of early warning signals in the absence of historical baseline data (C. Robertson et al., 2011). Regardless, project timelines must be sufficiently lengthy to allow for system design, implementation, integration with pre-existing surveillance activities, and realization by researchers and government of the added value provided by the information generated (Vital Wave Consulting, 2009). Stakeholders should be aware of the limitations to early information outputs during the surveillance system design phase.

It is important to note that the IDSAS was never intended to become part of ongoing EID disease surveillance efforts in Sri Lanka. It was intended to help determine if mobile phone technology could be used in a low-resource setting to generate information on an animal population. However, early on it became clear that the IDSAS was in fact very efficient and effective at collection of data that details the domestic animal population served by FVSs in Sri Lanka. It was at this time that the possibility of continuation of the IDSAS following the end of the research period was raised. Concurrently there was a change of leadership in government that contributed to failing to maintain the IDSAS. While it remains highly praised at the DAPH, the leadership change has meant that department priorities are being re-examined and as a result the IDSAS remains on hold. However, the DAPH remains motivated to deploy mobile phones for targeted projects as they saw the value in this approach.

Mounting and maintaining future surveillance initiatives will depend on political will and investment in the human capital that is essential to their success (Vital Wave Consulting, 2009). While Chapters 2 and 3 highlight the need to engage high-ranking government representatives to make pre-diagnostic surveillance initiatives sustainable, the views of surveillance in Chapters 4 and 5 reflect only the perspective of FVSs in Sri Lanka and private cattle veterinarians in Alberta respectively. Previous research has shown that buy-in is critical to incorporation of surveillance pilot projects into government health care programs (Vital Wave Consulting, 2009). Future research initiatives might examine the motivations of stakeholders at different levels of government, producers, and farmers to engage in pre-diagnostic disease surveillance initiatives, their expectations for surveillance systems more generally, and the value they perceive in the information generated through surveillance initiatives. This type of research could inform future surveillance initiatives to ensure they meet the needs of a wider range of stakeholders, which would foster greater collective enthusiasm for surveillance and therefore promote sustainability.

One of the primary deficiencies in the IDSAS highlighted in Chapter 3 was unidirectional flow of information: data flowed through the system and was delivered to stakeholders at the DAPH in a timely fashion but FVSs did not enjoy the same access to information. In Chapters 4 and 5, both FVSs in Sri Lanka and cattle veterinarians in Alberta cited the importance of information generated and fed back through surveillance programs as an incentive for participation. In order to improve future animal pre-diagnostic surveillance systems, means of enabling automated two-way flow of information and linking and integration of multiple data sources needs to be explored. Advancements in mobile phone and communication technologies on their own will address some of the challenges to two-way flow of information encountered during the IDSAS experience. During the process of garnering support for surveillance initiatives, discussions with stakeholders need to address any security issues they might have in order to clear the way for two-way flow of information. This raises a number of issues around data confidentiality including who should have access to information and how detailed should this information be. The more widely information is spread, the greater the risk of it being spread to individuals and organizations who may draw their own conclusions and use it for purposes for which it was not intended. Addressing many of these challenges early in the process of surveillance system design through discussions of the needs and concerns of stakeholders at all levels, including data submitters, would be of benefit in determining how to best disseminate information while ensuring concerns around privacy and confidentiality are addressed.

Directions for future research

The environments of domesticated food animals are characterized by a unique set of interactions among animals, humans, and pathogens and are driven by a variety of ecological, social, and economic factors (Leibler et al., 2009). While there have been a number of studies that have looked at the ecological dynamics that have led to pathogen spillover from wildlife populations (Daszak, Cunningham, & Hyatt, 2000; Woolhouse, 2002), the environments of domesticated food animals are usually not recognized as ecosystems (Leibler et al., 2009). One characteristic unique to food animal production ecosystems is they have an environment designed to maximize profit, as opposed to promote sustainability or reduce the risk from infectious diseases (Leibler et al., 2009). While certain design characteristics, such as spatial concentration, are optimal from the perspective of profit in the livestock industry they have serious adverse consequences to EID emergence and control (Leibler et al., 2009).

This study targeted animal health surveillance for early *detection* of EID risks and demonstrated the importance of the human dimension to this process. Further, it documented that motivation in the animal health field depends on more than monetary compensation. I would argue that future studies need to examine the human dimension of *mitigation* of EID risks in animal populations. In order to promote food production systems that are less likely to drive EID events and more resilient to EID risks, policies and regulations will need to consider ecological, economic, and social factors that interact in food animal production systems to reduce the risk posed by EIDs. This type of study would be particularly relevant in low-resource countries, where food production ecosystems are changing rapidly and the risk of future EIDs is highest.

One of the challenges to promoting enthusiasm for pre-diagnostic surveillance methodologies, and the practice of surveillance more generally, is that while it is possible to cite instances where these methods served to forecast an outbreak (Lemay, 2008; Rouquet et al., 2005), it is impossible to point to a pandemic that was averted as a result of surveillance in humans or animals. A recent report called for foresight in Canada's thinking and approach to animal health based on Canada's recent experiences with WNv, BSE, and avian influenza (Willis et al., 2011). Foresight employs an approach to thinking about the future that includes: a long timeline; multiple, plausible future scenarios; recognition of uncertainty and diversity; and highlights emerging opportunities and potential threats (Willis et al., 2011). It has the potential to inform today's decisions that impact future animal and public health. Recent experience with EIDs highlights the need for foresight in animal health to better anticipate, detect, and respond to the risks posed by EID events. In addition, as the public health community continues to be caught off guard by EIDs, linking research and policy initiatives with foresight of the risk posed by EID events could enable a reduction in vulnerability to these risks. My research shows that this process will need to take a global perspective on emerging opportunities that includes an understanding of human dimensions to be most effective.

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