ISSN 1466-2523

Animal Health Research Reviews 14(2); 147–150
doi:10.1017/S1466252313000121

Surveillance tools and strategies for animal diseases in a shifting climate context

Mo D. Salman

Animal Population Health Institute, College of Veterinary Medicine and Biomedical Sciences, Colorado State University, Fort Collins, CO, 80523, USA

Received 5 March 2013; Accepted 27 May 2013; First published online 23 October 2013

Abstract

Animal disease surveillance is watching an animal population closely to determine if a specific disease or a group of diseases makes an incursion so that a prior plan of action can be implemented. The purpose of this paper is to review existing tools and techniques for an animal disease-surveillance system that can incorporate the monitoring of climate factors and related data to enhance understanding of disease epidemiology. In recent decades, there has been interest in building information systems by combining various data sources for different purposes. Within the field of animal health, there have only been limited attempts at the integration of surveillance data with relevant climate conditions. Statistical techniques for data integration, however, have been explored and used by several disciplines. Clearly the application of available techniques for linking climate data with surveillance systems should be explored with the aim of facilitating prevention, mitigation, and adaptation responses in the surveillance setting around climate change and animal disease risks. Drawing on this wider body of work, three of the available techniques that can be utilized in the analysis of surveillance data with the available climate data sets are reviewed.

Keywords: disease surveillance, climate change, animal disease risk, disease monitoring, meta-analysis, path analysis, time-series analysis

Introduction

Disease surveillance is the key to early warning of a change in the health status of any animal population (Schwabe *et al.*, 1977). It is also essential to provide evidence about the absence of diseases or to determine the extent of a disease that is known to be present. Animal disease surveillance and survey programs enable veterinarians and others involved with the well-being of animals to detect either the emergence of a new disease or an unusual increase in an endemic disease.

The two terms 'surveillance' and 'monitoring' are often used interchangeably in animal health programs (Salman, 2003). Animal disease surveillance is watching an animal population closely to determine if a specific disease or a group of diseases makes an incursion so that a prior plan of action can be implemented (Doherr and Audige, 2001; Thurmond, 2003). Monitoring of animal diseases focuses on identifying a disease or a group of diseases to ascertain changes in prevalence, and determine the rate and direction of disease spread. Therefore, monitoring by definition lacks action to prevent or control a health problem. Surveillance, on the other hand, includes an action to prevent or control the health problem that is being monitored. In actual field situations, monitoring usually follows early reaction should surveillance activities indicate introduction or spread of a disease. Weather and climate factors are usually monitored on a regular basis either locally or globally with the aim to forecast climate conditions to predict impacts on agriculture and livestock production systems and/or other areas of life.

Many of the approaches used to implement monitoring can be used for surveillance and vice versa. In practical terms, the distinction between these two terms often becomes blurred. The differentiation, however, pertains

E-mail: m.d.salman@colostate.edu

more to the objectives than the applied approaches. Regardless of the used terms, both surveillance and monitoring include observations of the potential associated factors with the spread of the diseases such as climate factors. Approaches for a surveillance system should include tools and techniques that are capable of capturing the required data so that the comprehensive assessment of the disease under consideration can be conducted. The purpose of this paper is to review existing tools and techniques for an animal disease-surveillance system that can incorporate monitoring of climate factors and related data as part of understanding the disease epidemiology. The intention is to explore useful and reliable techniques for integration of data sets that represent animal disease-surveillance data and climate conditions.

Epidemiology and climate conditions

Understanding the epidemiology of a disease depends on the intersection of three main components: host, agent, and environment. Although the environment component can be generalized to wide areas of factors that can influence the introduction and the spread of the disease, climate and weather factors are an important part of this component. Infections and diseases are influenced by the past and current climate conditions that can affect both hosts and agents. Thus, a surveillance system should, as much as possible, consider the relevant climate factors in order to have an effective assessment of the disease and its control measures (see Lindgren *et al.,* 2012). Data collection for the surveillance system should synthesize with the real-time climate factors during the collection of observational data and previous climate conditions as prior knowledge to determine their actual effect on the behavior of the disease or its infection.

Factors affecting the spatial and temporal positions of pathogens, hosts and vectors, and their probability of a close encounter, are fundamentally important to disease dynamics. The intersection of host and pathogens is influenced by these factors including the meteorological conditions such as humidity, wind, sunlight, and temperature fluctuation among others (see Reperant *et al.*, 2010). In most cases, the probability of transmission of the pathogens to the host solely depends on these factors and others for the infection to become established. Spatial factors are usually investigated using popular specific remote sensing techniques including risk and/or geographical mapping tools. Although some of the climate factors can interact with spatial factors, the majority of the outputs from the spatial analysis have not included the link to microclimate or macroclimate conditions. Temporal factors, including climate characters, are usually investigated in relation to the surveillance data using statistical techniques such as time series analysis.

Surveillance data and their link to weather conditions

A surveillance system depends on data collection methods and measurement of the health events. Climate data from the same location and time period where a surveillance system is implemented should be part of the data collection system. Therefore, the system should incorporate the available climate and weather information during data collection. The data for meteorological conditions, however, in most occasions are collected for other reasons and they are separated both administratively and professionally from the implementers of the surveillance system. Thus, data collection for surveillance should utilize tools and techniques for integration of various data sets with the aim to derive reliable interpretations of the various factors that affect the introduction and/or spread of a disease in animal populations. This type of integration should be done prior to analyzing the data or producing reports. Techniques for integration of various sets of data therefore should be explored for better and effective animal disease-surveillance systems.

Available techniques and tools for the integration of weather and surveillance data

Data integration involves combining various data sets obtained from different sources and providing users with a unified view of these data (Lenzerini, 2002). The main aim of this process is to optimize the use of various data sets to obtain a reliable conclusion on a specific outcome such as a disease trend. During the last couple of decades, there has been interest in building information systems utilizing various data sources (Martin *et al.*, 2007) and dissemination mechanisms (Robertson *et al.*, 2010; Lin and Heffernan 2011). The traditional approach to building information systems has only been used in research with limited application in the integration of surveillance data with relevant climate conditions. Statistical techniques for data integration have been explored and used by several disciplines. Below are three of these available techniques that can be utilized in the analysis of surveillance data with the available climate data sets. These techniques have been validated and their limitations are already recognized. Nevertheless their benefits for surveillance data analysis have not been explored.

Meta-analyses are statistical techniques used for integration of different findings or sets of data with the aim to derive common conclusions of specific outcomes. Meta-analyses allow control among the variations in studies or sets of data (Greenland and O'Rourke, 2008). Although these techniques have been used in the system review process and clinical trials, their application in surveillance data is limited. Lack of interest in the integrations of data sets from various sources in assessing the trend from surveillance outcomes is the main reason for the limited use of meta-analysis in surveillance data. Quantitative epidemiologic indices (e.g. odds ratios, relative risk ratio, confidence intervals) are valuable tools in meta-analyses particularly with the ability to adjust for potential confounding factors and other biases. The main limitations for meta-analyses are related to the inconsistency in the measurement due to the various units of study from different sources of data sets and the potential for various time units in the measurement. Both these limitations can be adjusted using reliable statistical techniques, which are beyond the scope of this review.

Path analysis is used to describe the directed dependencies among a set of variables that can be obtained from various sets of data (Wright, 1921). This includes models equivalent to any form of multiple regression analysis, factor analysis, canonical correlation analysis, discriminant analysis, as well as more general families of models in the multivariate analysis of variance and covariance analyses. This technique has been applied in a vast array of complex modeling areas, including epidemiological studies, sociology, and econometrics. The technique can be classified as a form of multiple regressions focusing on causality. The structure equation model can be derived from a conceptual relationship by the surveillance analysts where the disease under consideration is the primary outcome. The equation model is constructed using both surveillance data outcomes and their relevant climate conditions. This type of equation model requires several assumptions particularly in linking the biological behavior of the disease in relation to the climate conditions. The integration of two or more data sources in building the model is a challenge that should be assessed for its logical and scientific validity. The path model may require more than one multiple regression equation before a final structure is completed. This type of approach can be useful in assessing the short and long-term impacts of the climate conditions while adjusting for other potential associated factors such as management variables.

Time series analysis is one technique, which has been widely applied in veterinary epidemiology in an attempt to better describe or predict the disease clustering in time (Courtin *et al.*, 2000). Time series analysis is useful in describing long-term patterns and identifying unusual deviations but the technique relies on a relatively long series of observations, typically well in excess of 50 observational time periods. Therefore, this technique may not be appropriate when animal disease surveillance data are limited by a time period. Data of meteorological conditions, however, are usually collected for several time periods; thus time series analysis has been used to predict or understand the weather pattern. Unfortunately very limited attempt has been made to associate the weather pattern as an output from time series analysis with animal health events. The exception is for a few vector-borne diseases in which this type of link was done (Heffernan *et al.*, 2012).

Data snooping

The above exploration of the use of various data sources should be differentiated from data snooping. Data snooping (sometimes referred to as data fishing or data dredging) is the inappropriate utilization of data mining that may lead to erroneous relationships or trends (i.e. statistical bias) (Smith and Shah, 2002). This type of bias should be avoided as much as possible in using various data sources particularly data of meteorological conditions, which are usually large and population-based data sources. The avoidance of such bias requires careful evaluation of the conceptual hypothesis and a full understanding of the variables in the data sets. There is, therefore, a requirement for interdisciplinary explorations of the conceptual hypothesis for surveillance data in conjunction with climate conditions.

Conclusions

Although to date some informative work has been done to incorporate weather conditions with surveillance data for animal diseases, much scope remains for additional explorations and future planning for animal disease-surveillance systems. Available techniques for linking climate data with surveillance systems require better explication to enhance and facilitate prevention, mitigation, and adaptation responses in the surveillance setting around climate change and animal disease risks particularly those associated with agriculture animals.

References

Courtin F, Carpenter T, Paskin RD and Chomel BB (2000). Temporal patterns of domestic and wildlife rabies in Central Namibia stock ranging area, 1986–1996. *Preventive Veterinary Medicine* **43**: 13–28.

Doherr MG and Audige L (2001). Monitoring and surveillance for rare health-related events: a review from the veterinary perspective. *Philosophical Transactions of the Royal Society B* **356**: 1097–1106.

Greenland S and O' Rourke K (2008). Meta-analysis. In: Rothman KJ, Greenland S, Lash T. (eds) *Modern Epidemiology*, 3rd edn. London, UK: Lippincott Williams and Wilkins, pp. 51–80.

Heffernan C, Salman M and York L (2012). Livestock infectious disease and climate change: a review of selected literature. *CAB Reviews* **7**: 1–26.

Lenzerini M (2002). Data integration: a theoretical perspective. In: Proceedings of the 21st ACM SIGACT-SIGMOD-SIGART Symposium on Principles of Database Systems (PODS 2002), pp. 233–246.

Lin Y and Heffernan C (2011). Accessible and inexpensive tools for global HPAI surveillance: a mobile-phone based system. *Preventive Veterinary Medicine* **98**: 209–214.

Lindgren E, Andersson Y, Suk J, Sudre B and Semenza J (2012). Monitoring EU emerging infectious disease risk due to climate change. *Science* **336**: 418–419.

Martin P, Cameron A and Greiner M (2007). Demonstrating freedom from disease using multiple complex data sources:

a new methodology based on scenario trees. *Preventive Veterinary Medicine* **79**: 71–97.

Reperant LA, Fuckar NS, Osterhaus A, Dobson A and Kuiken T (2010). Spatial and temporal associations of outbreaks of H5N1 influenza virus infection in wild birds with the 0° isotherm. *PLoS Pathogens* **6**: e100854.

Robertson C, Sawford K, Samson D, Nelson T and Stephen C (2010). Mobile phone-based infectious disease surveillance system, Sri Lanka. *Emerging Infectious Diseases* **16**: 1524–1531.

Salman MD (2003). Surveillance and monitoring for animal health programs and disease survey. In: Salman MD (ed.) *Animal Disease Surveillance and Survey System Methods and Applications*. Ames, Iowa: Blackwell Publishing Professional, pp. 3–13.

Schwabe CW, Riemann HP and Franti CE (1977). *Epidemiology in Veterinary Practice*. Philadelphia: Lea & Febiger.

Smith GD and Shah E (2002). Data dredging, bias, or confounding. *British Medical Journal* **325**: 1437.

Thurmond M (2003). Conceptual foundations for infectious disease surveillance. *Journal of Veterinary Diagnostic Investigation* **15**: 501–514.

Wright S (1921). Correlation and causation. *Journal of Agricultural Research* **20**: 557–585.