ANIMAL DISEASE SURVEILLANCE AND SURVEY SYSTEMS

Methods and Applications

Edited by
M. D. Salman
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Blackwell Publishing
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Preface

Most of the textbooks for epidemiology and veterinary medicine mentioned surveillance and survey as approaches to monitor and subsequently prevent the spread of diseases. Most of these books, however, assume that readers and users of epidemiology have the knowledge to excuse scientifically based plan for surveillance program. There are several methodological issues that need to be considered before such planning. Although some of these issues have been addressed in some of these textbooks, their relevant values to surveillance or monitoring were not included. Furthermore, most of these excellent books in epidemiology and preventive medicine have ignored the potential implementers and users of surveillance programs—specifically, government, international organizations, and public health agencies. Such users may require different ways to present information with more instruction on how to do it and fewer academic concepts. This book attempts to satisfy the requirements for an effective and scientifically sound surveillance for animal diseases or other health issues. Both concepts and examples are given for several of the approaches to such surveillance systems. The intention is to avoid in-depth academic elaboration of specific issues, as such elaboration is found in other classical textbooks.

Mo Salman
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ANIMAL DISEASE SURVEILLANCE AND SURVEY SYSTEMS

Methods and Applications
SURVEILLANCE, MONITORING, AND SURVEYS

Definitions

Disease monitoring describes the ongoing efforts directed at assessing the health and disease status of a given population. The sampling of individuals from the population to assess disease or health status may be ongoing or repeated. The disease monitored may be a specific infectious disease, a specific production disease, or disease/health in general. The population may be de-
fined at the national, regional, or herd level. For an alternative definition see Table 1.1.

**Disease surveillance** is used to describe a more active system and implies that some form of directed action will be taken if the data indicate a disease prevalence or incidence above a certain threshold. Similar to disease monitoring, sampling of individuals from the population to assess disease or health status may be ongoing or repeated, and the population may be defined at the national, regional, or herd level. Surveillance is usually directed at a specific disease. Disease surveillance systems require three components: a defined disease monitoring system, a defined threshold for disease level (predefined critical level at which action will be taken), and predefined directed actions (interventions).

A **disease control program** (DCP) is the combined system of monitoring and surveillance, disease control strategies, and intervention strategies that over a prolonged period of time is employed to reduce the frequency of a specific disease.

A **disease eradication program** (DEP) is a special case of a DCP in which the objective of the program is to eliminate a specific disease (the organism causing the disease).

The term “surveillance” was first used during the French Revolution, when it meant “to keep watch over a group of persons thought to be subversive.” The term has been used extensively by epidemiologists and other animal health professionals in the context of monitoring and controlling health-related events in animal populations. Disease surveillance is the key to early warning of a change in the health status of any animal population. 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. The terms “surveillance” and “monitoring” are often used interchangeably in animal health programs. Animal disease surveillance is watching an animal population closely to determine whether a specific disease or a group of diseases makes an incursion. Monitoring of animal diseases focuses on identifying a disease or a group of diseases to ascertain changes in prevalence and to determine the rate and direction of disease spread. Therefore, by definition, monitoring lacks action to prevent or control a health problem. Surveillance, however, 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. 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 more to the objectives than to the approaches applied.
<table>
<thead>
<tr>
<th>Textbook</th>
<th>Definition of monitoring</th>
<th>Surveillance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Martin et al. 1986</td>
<td>Animal disease monitoring describes the ongoing efforts directed at assessing the health and disease status of a given population.</td>
<td>The term “disease surveillance” is used to describe a more active system and implies that some form of directed action will be taken if the data indicate a disease level above a certain threshold.</td>
</tr>
<tr>
<td>Thrusfield 1995</td>
<td>Monitoring is the making of routine observations on health, productivity, and environmental factors and the recording and transmission of these observations.</td>
<td>Surveillance is a more intensive form of data recording than monitoring.</td>
</tr>
<tr>
<td>Noordhuizen et al. 1997</td>
<td>The routine collection of information on disease, productivity, and other characteristics possibly related to them in a population.</td>
<td>An intensive form of monitoring (q.v.). Designed so that action can be taken to improve the health status of a population; therefore, it is frequently used in disease control campaigns.</td>
</tr>
<tr>
<td></td>
<td>Monitoring refers to a continuous, dynamic process of collecting data about health and disease and their determinants in a given population over a defined time period (descriptive epidemiology).</td>
<td>Surveillance refers to a specific extension of monitoring where obtained information is used and measures are taken if certain threshold values related to disease status have been passed. It, therefore, is part of disease control programs.</td>
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The term “survey” is used to indicate an investigation or a study in which information is systematically collected for a specific aim or conceptual hypothesis. The time frame for this type of investigation is a specific and usually short period of time. This is in contrast to surveillance and monitoring, which involve the ongoing systematic collection of data and information. Surveys are more frequently used to answer a specific research question oriented toward a scientific and exploratory purpose. Approaches used for survey studies are similar to those used for surveillance and monitoring. In concept, a series of surveys can be considered as a monitoring system that may transition into a surveillance system if action is taken to prevent or control the disease. Therefore, the terms “surveillance,” “monitoring,” and “survey” share several common components, and hence, it is logical to consider them as a single topic for the purpose of this book.

Some authors have proposed the use of the term “monitoring and surveillance system” (MOSS) to summarize the concepts and approaches (Doherr and Audigé 2001; Noordhuizen et al. 1997; Stärk 1996). In that context, monitoring describes a continuous, adaptable process of collecting data about diseases and their determinants in a given population, but without any immediate control activities. Surveillance is a specific case of monitoring in which control or eradication measures are implemented whenever certain threshold levels related to the infection or disease status have been exceeded. By definition, surveillance is therefore part of any disease control program (Noordhuizen et al. 1997; Office International des Epizooties [OIE] 1998, 2000). The term “MOSS” will be used hereafter in this book, and surveys are included in this term unless otherwise mentioned.

**DATA COLLECTION METHOD FOR MOSS**

One of the main components for any MOSS is the collection of data, which can be classified as either passive or active. Unfortunately, some authors have generalized these terms as labeling surveillance as passive versus active (Lilienfeld and Stolley 1994). A surveillance system cannot be passive if an action is part of its definition. Therefore, in this book the use of the terms “active” and “passive” will be only used to refer to the data collection method.

An active collection of data for a MOSS is referred to as the systematic or regular recording of cases of a designated disease or a group of diseases for a specific goal of monitoring or surveillance. A population determined by specific location or time period is usually defined for the system. This should provide each individual within the defined population with a known and often equal chance of being selected. The identification of such an appropriate pop-
ulation depends on the event of interest, its expected prevalence, and the available diagnostic tests. Another chapter (Chapter 4) of this book details the sampling techniques for this type of MOSS.

Information about the health-related event might be collected from owners by interview or mail. Biological samples might be collected during farm visits or at abattoirs, knackeries, or carcass rendering plants. In addition, the screening of animal medical records (either the files or electronic databases) for specific entries or the screening of biological sample banks for specific pathogens or lesions can be considered part of the active collection of data for a MOSS. Examples of such a system include the tuberculosis and brucellosis MOSSs that are routinely performed in several countries of the world, infectious bovine rhinotracheitis (IBR) and enzootic bovine leucosis (EBL) sero-surveys in Switzerland (Stärk 1996), abattoir screening for contagious bovine pleuropneumonia (CBPP) in Switzerland (Stärk 1996), bovine spongiform encephalopathy (BSE) screening of fallen stock and emergency slaughtered cattle in Switzerland and Europe (Doherr et al. 1999, 2001) and of “downer cows” in the United States (http://www.aphis.usda.gov/lpa/issues/bse/bse.html). Other examples would be the scrapie surveillance in the United Kingdom (Simmons et al. 2000) and postal surveys for scrapie in the United Kingdom, the Netherlands, and Switzerland (Baumgarten et al. 2002; Hoinville et al. 1999, 2000; Morgan et al. 1990; Schreuder et al. 1993). Some national MOSSs include mail or interview questionnaires as well as collection of biological samples for laboratory testing (Kane et al. 2000; Traub-Dargatz et al. 2000a, 2000b; Wagner et al. 2000).

A major disadvantage of the active data collection for a MOSS, when population-based, is that it is very costly when the occurrence of the target disease is rare. The lower the disease prevalence, the larger the sample size required for detection. Once the prevalence becomes very low (<0.1%), it often is not feasible to further increase the sample size because of funding constraints, because of limitations in the working capacity of diagnostic laboratories, or simply because of limitations of the chosen test system (e.g., the tests are not sensitive and specific enough to distinguish between zero and very low prevalence levels). The situation changes from low prevalence to the probability of disease freedom. Instead of prevalence estimation, the focus is now on the identification of a health-related event if it occurs in the defined population above the threshold prevalence. An example in which all animals in a defined population are tested is the mandatory fallen stock surveillance for BSE in Europe. Within this program, because of the expected very low prevalence (<0.1%) of detectable cases, all fallen cattle more than 24 months of age have to be examined. Between January 2001 and April 2002, the average prevalence
in this high-risk target population was approximately 0.05%—or one case per 2,000 samples tested (http://europa.eu.int/comm/food/fs/bse/testing/bse_results_en.html).

The passive collection of data involves the reporting of clinical or subclinical suspect cases to the health authorities by health care professionals, at their discretion (Lilienfeld and Stolley 1994). Therefore, the validity of the system depends solely on the willingness of these professionals to secure the flow of data. In veterinary medicine, the passive collection of data can be influenced by the awareness and level of knowledge of a particular disease among veterinary practitioners and producers or owners of animals. Another important component of this type of data collection is the availability of a diagnostic laboratory scheme to support and confirm cases. The main limitation of passive data collection is inconsistency in the data collection for different diseases and among communities that provide the data. Thus, a comparison of various passively collected MOSS data should be approached with caution. Disease awareness, educational level of the MOSS data providers (practitioners, regulatory veterinarians, and owners/producers), and the nature of the disease under the MOSS are the major elements in the effectiveness of the MOSS. For instance, a disease with a high case-fatality rate may be reported more frequently than a disease with a low case-fatality rate. A disease with more public awareness (e.g., one that has had extensive advertising or educational programs) may be more likely to be reported compared with a disease with less awareness, even though its true prevalence and incidence are lower. It should be also noted that the use of the passive collection of data would not ensure the early detection of a disease.

Passive collection of data for a MOSS can identify a change in a pattern that may warrant further investigation. Typically, an active method of collection of data then can be implemented. For instance, the first few BSE cases found in the United Kingdom at the initial epidemic were reported using the passive collection of data for a MOSS that was not designed specifically for collection of BSE cases. Then a MOSS was implemented to actively collect data for BSE.

Some countries have used the term “notifiable animal diseases” for those diseases that are required by law to be reported. Most of the OIE List A and specific zoonotic diseases fit the criteria to be on the notifiable list. Although these notifiable diseases by definition should require active collection of data for a MOSS, most countries have used passive collection of data for MOSSs. The main reason for this is the lack of a well-planned study design to maintain and actively detect cases for these diseases.

Other authors (Doherr and Audigé 2001; Dufour and Audigé 1997) have classified MOSS activities by the method of data collection into three classes: passive, active, and sentinel networks. Baseline data collection was considered a subcategory of passive collection. In my opinion, a disease trend that is de-
termined by surveillance is different from baseline data. Disease trends can change over time, and the use of the term “baseline data” in this context may be misleading. The term “sentinel networks” refers to a method for actively collecting data for a MOSS using a selected sample to represent the population. Chapter 8 discusses details of the use of sentinel herds for MOSSs.

**TARGETED SURVEILLANCE**

The term “targeted surveillance” is becoming popular, and it principally refers to focusing the sampling for the MOSS on high-risk populations (i.e., targeted populations) in which specific commonly known risk factors exist. An example of a target population is fallen cattle stock in Europe, because this high-risk group of cattle has more BSE than otherwise healthy cattle. Another target population is specific hamburger meat processed in large quantities, which is associated with a greater risk of *Escherichia coli* O157:H7 than unprocessed meat.

The main purpose of implementing this surveillance approach is to increase the efficiency of the system. This design is appropriate when the following two conditions exist: the disease under consideration is less common in the general population than in the targeted group, and specific risk factors are established or known. Therefore, prior knowledge about the disease and its epidemiology is required before this design can be considered. On occasion, targeted surveillance is used to ensure the absence of a specific disease from a highly susceptible population. For instance, the purpose of the surveillance in the United States of downer cows and cattle with suspected neurological signs of BSE is mainly to provide evidence of the absence of BSE.

Targeted surveillance is an effective design to purposely implement an action that can reduce the effect of a disease rapidly. An example of this approach is a nosocomial infection MOSS in a veterinary teaching hospital in which equine colic cases are targeted for *Salmonella* surveillance. This is because of the fact that these cases are more susceptible to this infection than other hospital-admitted cases (Kim et al. 2001; Tillotson et al. 1997).

**EFFECT OF THE CHANGE IN TRADE REGULATIONS ON MOSS PLANNING AND IMPLEMENTATION**

Among the agreements that were included in the treaty that established the World Trade Organization (WTO) is the Agreement on the Application of Sanitary and Phytosanitary Measures (SPS) Agreement, which sets out the basic
rules for food safety and animal and plant health standards. The SPS Agreement has truly changed the way in which trade decisions related to agricultural products are made. Its main intent is to avoid the use of SPS measures as unjustified barriers to trade. Although recognizing the right of countries to protect human health and agricultural health, the agreement dictates that all measures must be scientifically based and not unnecessarily restrictive. Specifically, the SPS agreement has placed an increased emphasis on the importance of sanitary and phytosanitary measures, requiring improved surveillance and monitoring systems, adequate laboratory diagnosis, risk analysis capabilities, and quality assurance. The agreement demands that a country demonstrate its animal health status by means of scientifically based surveillance efforts. Thus, a country’s veterinary services, livestock industries, and international agencies are paying attention to the design, implementation, and outcomes of MOSSs for animal diseases in both animals and animal products (Zepeda et al. 2001).

In several countries, the demand for scientifically reliable MOSS has coincided with a reduction in budgetary and human resources among the government veterinary services. These countries, therefore, have attempted to identify the most efficient methods to satisfy the national and international requirements for animal health. During the last decade, numerous methods and approaches for MOSS in animal health programs have been discussed or proposed. The most important outcome from this type of exploration is the determination of the absence of the disease or its agent from a country; that is, when prevalence of a disease is at or near zero. The objective of this type of MOSS is to provide evidence (with known confidence) that a disease or pathogen, if present in a zone or country, is present at or below an acceptably low (practically undetectable) prevalence. Although it will probably continue to be commonly used, the term “freedom from disease” is potentially misleading. Freedom implies complete absence, which is analogous to the now unacceptable concept of zero risk.

Current approaches generally involve the compilation of evidence from a range of sources and the use of this evidence to put forward a convincing argument about a country’s disease status. One source of evidence that is commonly used or demanded is a structured statistically valid survey. The primary advantages of the use of surveys are that well-established theory and methodologies exist and that they are able to produce a quantifiable probability estimate for the presence of disease. International regulations increasingly demand that the level of proof of disease status meets quantitative standards; for example, that the probability of the presence of disease at a prevalence in animals of 0.2% or greater is less than 1%. Other sources of evidence that may be used include passively collected data, an assessment of the quality of the vet-
erinary services, livestock movement history, geographical and environmental factors, abattoir monitoring, sentinel herds, and so forth.

It has become clear that there are a number of problems with this approach. Structured surveys are often too expensive or impractical to achieve the level of proof required. This is a result of the very large sample sizes necessary when the prevalence is very low and when applied tests do not have very high sensitivity and specificity. This difficulty is further complicated by variability in sensitivity and specificity and by a lack of reliable estimates of these test accuracy parameters for the population under study.

As a result, true disease status cannot always be determined through the use of surveys alone. It is necessary to combine all the different sources of evidence available to assess the overall probability that a disease does not exist or is below the threshold prevalence. Until now, however, there have been no accepted methodologies for either quantifying the evidence provided by passive collection of data for a MOSS or combining probability estimates from multiple different sources into an overall estimate of the probability of absence of the disease. It is proposed that these problems may now be overcome through the use of a range of different analytical methods, including

- a standardized approach to scenario tree analysis and stochastic simulation to estimate the power of a complex MOSS (A. Cameron, personal communication),
- improved use of techniques to elicit and combine expert opinion as additional information to data generated by a MOSS (K. Stärk, personal communication),
- methods to adjust the value of data sources for a MOSS based on the time that has passed since their generation (Schlosser and Ebel 2001),
- and Bayesian approaches to the combination of data from multiple sources of MOSS (Suess et al. 2002).

Regardless of whether one or a combination of the above approaches is used, there is a need to ensure that the principles behind it, and the tools required to implement it, are sound and made widely available to those who need it. The use of these approaches would require specific tasks:

1. Identify all possible sources of evidence for the absence of disease.
2. Analyze each source independently through the construction of a scenario tree to estimate the probability that an infected animal, if present, would be identified by the MOSS. At each branch of the tree, probability estimates and ranges are required. These should be derived from reliable