Sanitary and Phytosanitary Capacity Building Program (SPS CBP)

AusVet
Animal Health Services

Permission has been given to use this manual in the AB-CRC's *Short Course in Surveillance Systems*, 2-4 September 2008 (Brisbane).

Livestock Disease Management

Essentials

Volume 1

Surveillance

Australian Government
Department of Agriculture, Fisheries and Forestry
AusAID

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Part 1: Introduction

Introduction

> ***Surveillance is an essential component of Australia's preparedness for emerging and exotic diseases, as well as for the management of endemic diseases. However, much of the surveillance in Australia is done on an ad hoc basis and is often poorly structured and managed. One of the CRC's objectives is to provide new surveillance tools and methodologies. However, for this to be achieved it is also essential that animal health professionals understand how best to use these tools and methods to achieve the desired outcomes. This requires a thorough understanding of the principles of surveillance and the development of surveillance systems.***

This course aims to address this issue by providing improved knowledge and understanding of surveillance systems and their implementation and analysis for animal health practitioners in the field.

About the course

This course is designed to provide a simple and understandable introduction to surveillance systems for animal health professionals. It starts with the basic concepts and reasons for undertaking surveillance. It then builds on these concepts to develop an understanding of the range of approaches that can be used to undertake surveillance, depending on the specific purpose. Issues associated with planning and subsequent analysis of both random and targeted surveillance programs are covered, as well as the evaluation of surveillance systems.

The course is targeted primarily at animal health professionals responsible for undertaking disease surveillance or surveys at administrative, planning or field levels. This includes students undertaking postgraduate degrees, as well as researchers, laboratory professionals, animal health managers, epidemiologists and field staff.

Completion of the course will help you to understand:

- What is surveillance?
- How surveillance helps in making good decisions about animal health management.
- What are the main purposes of surveillance?
- What are the main types of surveillance?
- Approaches to collecting surveillance data.

- Requirements for effective surveillance.
- Practical implementation of surveillance systems.
- Analysis and use of surveillance data.
- Evaluation and improvement of surveillance systems.

The course notes

These notes have been adapted (with permission) from the manual developed within the SPS Capacity Building Program project 'Training in Integrated Risk Management for Livestock Diseases': *Livestock Disease Management* Essentials *Volume 1 Surveillance (2007)*

Background to the project

The Australian Government Department of Agriculture, Fisheries and Forestry has the dual roles of providing customer services to the agricultural, food, fisheries and forest industries, and addressing the challenges of natural resource management. It also helps build and promote the whole food and fibre chain from paddock to plate for domestic and international markets.

The Department's contribution to its customers is to help their industries become more competitive, profitable and sustainable.

The Sanitary and Phytosanitary (SPS) Capacity Building Program (CBP) is an AusAID-funded, three year, regional Program managed by the Office of the Chief Plant Protection Officer. In this role the Department is referred to as the Australian Managing Contractor (AMC).

The Program assists ASEAN (Association of South East Asian Nations) focal countries to:

- describe and manage their animal and plant health status; and
- implement SPS measures consistent with international standards and the expectations of trading partners.

This manual has been developed under the SPS Capacity Building Program - Training in Integrated Risk Management for Livestock Diseases, with the objective of providing basic training in integrated risk management for livestock diseases with particular emphasis on approaches to zoning in developing countries. The outcome of these activities will be improved capacity in the ASEAN region to plan and implement animal programs in disease risk management.

This manual has been developed (with the assistance of the United Nations Food and Agriculture Organisation (FAO), and the World Animal Health Organisation (OIE)) by experts from AusVet Animal Health Services working with regional specialists

It has been developed to support the first of three training workshops for regional practitioners and veterinary scientists, or regional managers with responsibilities in animal disease control for serious infectious diseases.

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Part 2: Surveillance

Contents

Introduction to Animal Disease Surveillance

Learning Objectives

After studying this chapter you should be able to:

- ☐ Understand how decisions about animal health management are made and what is required to make good decisions
- ☐ Provide a general definition of surveillance
- ☐ List the main purposes of surveillance
- ☐ Understand different terms used to classify surveillance activities, including *active, passive, targeted* and *general*, and be able to correctly classify a particular activity using these terms

There is no one right way to do surveillance. Many factors affect the decision on how surveillance should be undertaken and what information can be derived from the results.

This manual aims to introduce readers to the principles, issues and practice of surveillance in terrestrial animals.

A useful accompanying text with greater detail on planning, conducting and analysing surveys is *Survey toolbox for livestock diseases: a practical manual and software package for active surveillance in developing countries*. ACIAR, Canberra, Australia, 1999 by A.R Cameron.

Decision making and Animal Health Management

One of the key functions of the veterinary services in animal health management is to make decisions. There are many different decisions that must be made, such as:

- Should we allow the import of a certain product or species from a particular country?
    - If so, what controls should we require?
- Should we include a particular disease on our list of notifiable diseases?
- What are the most important messages we should try to communicate to farmers in our extension programs?
- How long should the quarantine period be for a particular species?

- is stamping out required to control an outbreak of a particular disease, or will vaccination or strict movement control be effective?
- is it worthwhile to establish a control program for a particular disease?
    - will the benefits be worth more than the cost of the control program?
- are there problems with food safety in the animal products in our country?
    - is the meat inspection system adequate? How can we improve it?
- is the vaccination program successful?
    - if not, how can it be improved?
- given the various animal health issues and almost always a finite set of resources, which issue do we prioritise or tackle first?

Some of these decisions are taken at a high level, and influence many people. Other decisions are smaller, such as:

- what is the best drug to use to treat this animal?
- should I send a diagnostic sample to the laboratory to confirm this diagnosis?
- should I sign this health certificate/movement certificate?

All of these decisions affect animal health management, some in a big way, some in a small way. It is important that these decisions are made, even if some are difficult, because failing to make a decision means that no action can be taken, and no progress is made.

In order to achieve *effective* animal health management, it is important not just to make decisions, but to make the right decisions. Many of the questions above are not simply technical, but also have social, political and economic aspects. All of these must be considered when we are making decisions.

Decisions therefore involve a combination of inputs including:

- experience
- political or social pressure
- intuition or guess-work
- identifying the easiest option.

However, *good* decisions that result in effective animal health management should always be based on objective evidence. Objective evidence is produced by the appropriate analysis of good information:

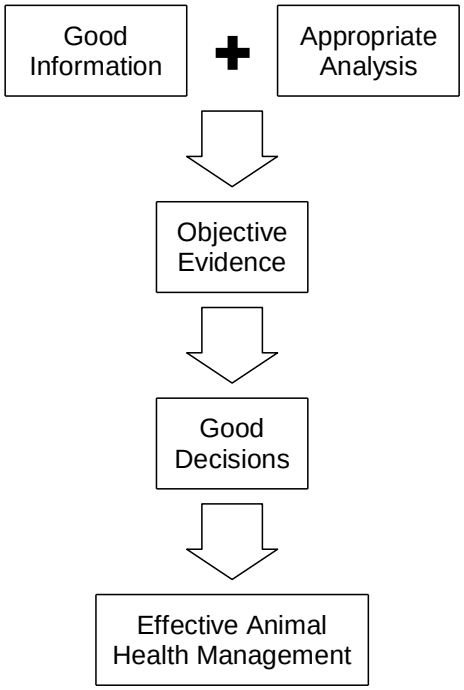


Figure 1: Making good decisions

Decision making would be easy if complete information was always available. For instance, if it is known that longest period for which an animal could transmit a disease after initial infection was three weeks, then decisions about the best quarantine period are easy to make.

However, in many cases, complete information is not available.

Consider decisions about whether a vaccination program is working or if it should be modified. Before the program was implemented, there were outbreaks of disease. After the program was implemented, there are still outbreaks of disease, but not as many.

Is this because:

- the vaccine is only partially effective against the existing strain?
- there are more than one strain of disease circulating?
- not all animals are being vaccinated?
- vaccine is not being administered correctly?
- vaccine is being distributed, but problems with the cold chain mean that some is not effective when given to the animal?
- some vaccine is being sold by the vaccination teams, rather than given to the animals?
- the level of disease has dropped dramatically, but the level of farmer awareness and reporting has increased, so the last few outbreaks are still being reported?
- outbreaks are still occurring, but the impact of the outbreaks is much lower (fewer animals are being affected or dying)?

If the only information available was that there are still outbreaks occurring, it would be very difficult to decide what to do about the vaccination program. The options include:

- continue as it is, as it is already effective
- stop it altogether as it is expensive and is not controlling disease
- modify the program, to improve it (but how?).

When complete information is not available, decision makers have three choices:

1. make a decision in the old way (based on politics, guesswork or the easiest option), and risk making a bad decision which will fail to improve the animal health situation
2. gather new information to allow better decisions to be made
3. collect and analyse all available existing information, and try to make the best decision possible even if there is not enough information to be completely sure.

The second option is clearly the best, but it is time-consuming and expensive. For important decisions, this is the best approach, whenever possible.

When it isn't possible to collect more information, the third option can be used.

Epidemiological data analysis (including tools such as risk analysis) provides a set of tools to help make good decisions in the absence of complete data. In the real world, we rarely have all the information we need, but epidemiological data analysis allows us to make the best possible decision given the available data. Good data analysis may be time-consuming, but not as many resources are required as when we try to collect more new information. When we use good epidemiological data analysis with incomplete data, we may not get the right answer all the time, but we will be right most of the time.

Information for decision making comes from a variety of sources:

- in the example about quarantine above, information on the best quarantine period may have been available from scientific journals
- however, for many of the decisions we make, such as those about a vaccination program, information comes from surveillance.

The figure above can therefore be extended:

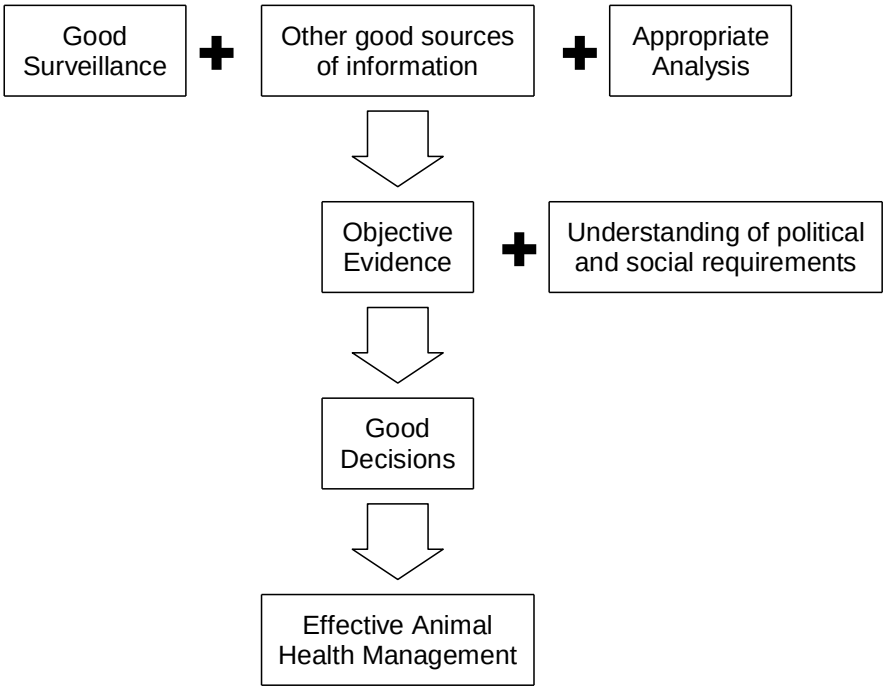


Figure 2: Making good decisions in the real world

What is surveillance?

Disease surveillance is all about collecting information to describe the health status of a population. The term 'monitoring' is also used to refer to closely related activities.

There are many different definitions for, and distinctions between, surveillance and monitoring, all with slightly different emphases, but the main features in most definitions relate to:

- systematic collection of relevant information
- timely collection of information
- on-going or continuous collection of information
- collection of information from populations or sub-populations
- methods distinguished by their practicability, uniformity, and rapidity, rather than by complete accuracy
- analysis, interpretation and communication of the collected data
- planned use of the collected data for decision making (surveillance) or absence of planned use (monitoring)
- a focus on measuring levels or detecting changes in endemic disease (monitoring), or of detecting incursions of new, emerging or exotic disease (surveillance)
- the nature of the characteristic of interest, (clinical disease, presence of a pathogen, evidence of immune response to a pathogen, or even presence of risk factors for a disease)

For the purpose of this volume, the term 'surveillance' will be used in a general sense to capture all the above variations (it therefore includes monitoring). The World Organisation for Animal Health provides a definition, which, while it does not capture all the aspects listed above, may act as a standard:

> "Surveillance means the investigation of a given population or subpopulation to detect the presence of a pathogenic agent or disease; the frequency and type of surveillance will be determined by the epidemiology of the pathogenic agent or disease, and the desired outputs."
>
> OIE Terrestrial Animal Code (2007).

The purposes of surveillance

While there may be some special cases, the purpose for most animal health surveillance can be divided into the following four categories:

- surveillance for diseases that are present
  - describing the level or distribution of disease (or a pathogen, or risk factors for disease)
  - assessing the progress of disease control or eradication programs
- surveillance for diseases that are absent
  - detecting the incursion of new, emerging or exotic diseases or pathogens, or their risk factors
  - demonstrating freedom from disease or pathogens.

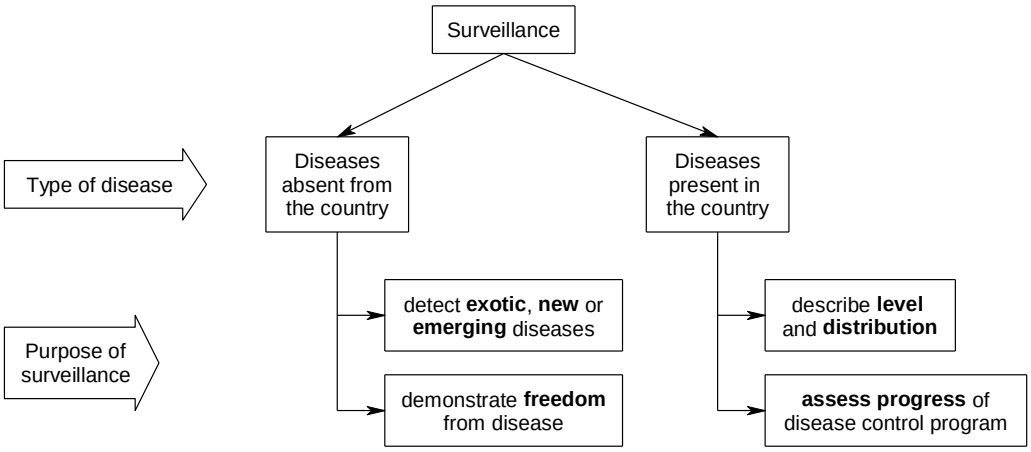


Figure 3: Classification of the purposes of surveillance.

Classification of surveillance activities

A number of terms are often used to describe surveillance activities, including:

- active
- passive

- targeted
- general.

These terms refer to two different aspects of surveillance.

Origin of the surveillance information (initiation of data collection)

Active surveillance describes a surveillance activity that is designed and initiated by the prime users of the data. The main purpose of the activity is disease surveillance.

Examples of active surveillance include:

- a serological survey to assess the prevalence of antibodies to brucellosis
- a farmer questionnaire to identify the level of mortality in their animals.

This is called active as the users of the surveillance data are *actively* involved in generating the data.

One of the significant advantages of active surveillance is that the activity is designed by the users of the information. It is therefore possible to ensure that both the nature of the data collected, and the quality of the data, are adequate to meet your surveillance requirements.

Passive surveillance describes a surveillance activity that uses data that has already been collected for some other purpose. The veterinary services do not initiate the data collection.

Examples of passive surveillance include:

- a farmer disease reporting system. In the process of seeking advice, diagnosis, or treatment for sick animals, the farmer 'reports' disease.
    - The reason for the farmer making the report is not to help the surveillance system, but to seek veterinary assistance for the problem with their animals.
    - The use of the data for surveillance is secondary.
- abattoir meat inspection.
    - The reason for the meat inspection is to ensure the quality of the meat sold to consumers.
    - If the data were not used for surveillance, meat inspection would still be required.

The main advantage of passive surveillance systems is that they are cheap

- as a result, they often can have much greater population coverage
- however, the data may not fully meet the veterinary services needs for surveillance data, and little control is possible over data quality

- the quality may be improved if farmers and veterinarians are educated or rewarded to improve reporting for specific conditions.

Disease focus

Targeted surveillance describes surveillance that is focused on a specific disease or pathogen.

For example, the serological survey for brucellosis mentioned above may use the Rose Bengal Test (RBT)

- blood from each sampled animal is tested, and the result of the test classified as RBT positive or RBT negative
- an animal that has tuberculosis or FMD, but which did not have brucellosis, would be simply classified as RBT negative, as these other diseases are not of interest in this surveillance activity.

General surveillance is not focused on a particular disease, but is capable of detecting any disease or pathogen.

For example:

- the farmer disease reporting system mentioned above is a general surveillance system, as any disease may be reported
    - note that not all diseases will be reported with the same reliability
    - farmers are more likely to report diseases that show clear signs and have a significant impact (e.g. many animals affected; or resulting in death, such as haemorrhagic septicaemia) more often than they report diseases that display few signs or do not result in an immediate economic impact (such as intestinal parasites).
- The use of some laboratory tests, such as histopathology, means that many different diseases are able to be detected, rather than just a single disease.

An important feature of general surveillance is that it is not only able to detect known diseases of interest, but may also be able to detect new, emerging, exotic or unknown endemic diseases

- in other words, it is not necessary to be looking for a specific disease in order to find it.

The distinction between general and targeted surveillance depends on the disease detection system used.

Targeted surveillance is based on the use of tests that are able to provide a yes/no answer for a specific disease.

Examples include:

- polymerase chain reaction (PCR)
- enzyme-linked immunosorbent assay (ELISA)
- agar gel immunodiffusion (AGID).

General surveillance is based on tests that are able to identify multiple diseases (in some cases, all diseases).

These tests include:

- clinical examination
- disease investigation
- post-mortem investigation
- meat inspection
- histopathology
- various syndromic surveillance activities.

Classification

Using these two ways of describing surveillance activities, it is possible to classify surveillance according to the following table.

Table 1: Classification of surveillance activities.

		Origin of information	
		Active	**Passive**
Disease Focus	**Targeted**	Structure serological survey	Use of dairy factory bulk milk cell count data to assess progress of mastitis control programs
	General	Structured survey of veterinary practitioners asking about the most common diseases they encounter	Farmer reporting system

Uses of surveillance data

Surveillance provides one of the key sources of information that we can use to make good decisions in other areas of animal health management including:

- risk analysis
- zoning
- farmer extension

- contingency planning

Activities

1. List all the surveillance activities that you are involved in, or have heard of.
2. For each of those activities, what is the purpose – why is it being done?
3. Classify the activities in terms of active/passive/targeted/general.

Approaches to Collecting Surveillance Data

Learning Objectives

After studying this chapter you should be able to:

- ☐ Understand how data is transformed into information
- ☐ List the different types of data that are collected by surveillance systems and how they can be used, including
  - diagnoses,
  - classifications,
  - specimens
  - syndromes and signs,
  - negative reports,
  - indirect indicators,
  - risk factors
- ☐ Understand the differences between surveillance based on sampling and that based on a census
- ☐ Understand representativeness and when a surveillance system may produce biased data
- ☐ Determine when biased surveillance is a problem, and when it may be acceptable or desirable
- ☐ Understand the principles and advantages of risk-based surveillance
- ☐ Use the principles in this chapter to decide on an appropriate surveillance strategy

Surveillance involves the systematic collection, analysis and response to disease information about populations.

This chapter deals with issue of how to collect surveillance data. It will consider the type of information that is collected, and then the mechanisms used to collect that information, and will provide a range of examples.

What is collected?

The information collected by a surveillance system is modified through the collection process.

Data and Information

In most cases, surveillance starts with data, which are the raw facts about the population.

For example, a veterinarian examining a sick animal may observe that the animal has a fever, is dehydrated and has a smelly discharge from the vulva. He may also learn from the owner that the animal had recently given birth. These facts are the data that the veterinarian works with. They are clinical signs and history, but may also include further facts about the population. The veterinarian then analyses this data, using his knowledge of disease and experience, to conclude that the animal probably has metritis. The data (signs) have now been turned into information. Information is interpreted data that provides some sort of conclusion.

At a higher level, there may be a report from the provinces listing the total number of cases of metritis that have been reported by all veterinarians in the country. Once again, it is possible to look at the diagnosis of metritis as a fact, or as a piece of data. This may then be interpreted through analysis to produce higher-level information perhaps by combining it with the estimated number of births in a period of time, to provide the incidence of metritis (e.g. two cases per 100 births).

In order to understand a surveillance system properly, it is important to be able to identify the original data items or facts that are collected, and any analytical steps that take place to generate information.

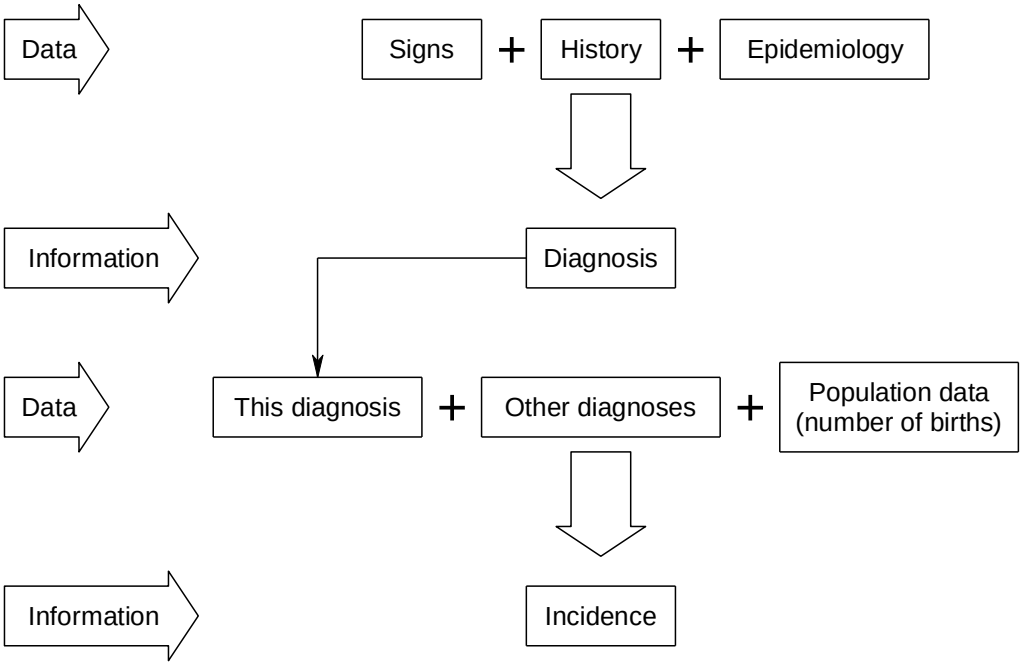


Figure 4: Transformation of data to information

This process clearly identifies that we started with signs, these were used to generate a diagnosis, then we needed more information (number of births) to calculate the final information that we needed (incidence of metritis).

Common data collected in a surveillance system includes:

- disease diagnoses
- syndromes or signs
- indirect indicators of disease
- risk factors for disease.

Diagnoses

At the individual animal level, a diagnosis tells us what disease an animal has.

In surveillance, it is used to classify some animals as having a particular disease (and other animals as not having that disease).

Diagnoses refer specifically to disease, usually clinical disease.

Classifications

Often, we are not interested solely in clinical disease, but in some characteristic of the animal that is related to disease.

- For instance, if we are doing a serological survey to demonstrate freedom from brucellosis, we are seeking to classify animals as seropositive or seronegative. Seropositive animals are unlikely to have disease – we are simply using the serological status to indicate if the animal has been exposed to the bacteria (or possibly a vaccine) at some time in the past.
- Similarly, surveillance to evaluate the progress of an FMD vaccination program, by estimating the proportion of animals that have protective antibodies, is not based on a diagnosis of disease, but on the antibody status of the animals.

Any measurable characteristic can be used to classify animals for the purposes of surveillance.

Specimens

Both the diagnosis of disease, and the classification of animals according to some characteristic (e.g. antibody status), usually are achieved using some type of test:

- some tests are laboratory-based, such as
    - an ELISA to measure antibody levels
    - virus isolation
    - PCR to detect a pathogenic agent
- other tests can be performed in the field
    - clinical diagnosis by a veterinarian can be thought of as a type of test for disease
    - meat inspection in an abattoir is also a test

When a laboratory test is used, the thing that is collected for surveillance is normally not the information but a specimen from the animal (blood, milk, a tissue sample etc). This specimen has a test applied, to produce a test result – the data we need.

Syndromes and signs

In the case of disease, the most commonly-collected information is the **diagnosis**.

In order to make a diagnosis, the animal should be examined by a veterinarian, and, if required, specimens submitted for laboratory testing.

This is not always possible, so some surveillance systems are designed to collect uninterpreted data, rather than the diagnosis that would result from its interpretation.

To make a **diagnosis**, a veterinarian will observe the *signs* shown by a sick animal (such as lameness, coughing, increased heart rate, etc), and interpret them to decide on the disease causing the problem. This diagnosis will usually be correct, but sometimes might be wrong.

Many of these *signs* are simple to observe by people without veterinary training:

- while non-veterinarians are unlikely to make a correct diagnosis, those that work with livestock are often very good at identifying clinical signs – abnormalities in their animals
- in some cases there are legal restrictions on who can make a diagnosis (usually only qualified veterinarians).
- village animal health workers are usually not veterinarians but are trained to recognise disease signs.

A surveillance system may therefore collect data on the *signs* of disease observed:

- changes in the patterns of signs observed in a population may indicate changes in the diseases that cause those signs. For instance, even if the diagnosis is not known, a sudden increase in the number of cases of disease showing signs of coughing probably indicates the introduction and spread of a respiratory disease.
- this information can be used to initiate a detailed disease investigation to determine what the cause of the coughing is.

To make interpretation and reporting of this type of surveillance simpler, cases are often classified into **syndromes** according to the key sign or group of signs:

- a syndrome is simply a defined collection of signs
    - in the above example, the syndrome may be 'respiratory disease' and include any case of disease that shows coughing, difficulty breathing and so on

- other syndromes may include:
    - 'acute febrile illness'
    - 'diarrhoea'
    - 'skin lesions'
    - 'sudden death'
    - 'lameness'.

Both reporting of signs and reporting of syndromes are referred to as **syndromic surveillance**:

- syndromic surveillance is usually designed to help with the detection of changes in disease patterns or the early detection of new diseases
    - when a change is detected, it must be followed up by more detailed investigations in order to determine the diagnosis of the disease causing the change.

Surveillance may collect data on the **signs** associated with a case of disease, or the general **syndrome** that describes that case of disease. The use of syndromes in data collection and reporting is more common than collecting signs. This is because with syndromes, there one data item per case (e.g. 'respiratory disease'), whereas when reporting signs, a single case may have many different signs associated with it (e.g. 'coughing', 'difficulty breathing', 'standing with neck extended', 'increased heart rate'), making reporting, collation and analysis of the data more complicated.

Negative reporting

Negative reporting is a special case of disease reporting:

- the data item in this type of surveillance is the fact that an animal *does not* have a specified disease.

Negative reporting data may be used in two ways:

1. to rule out key diseases in a **laboratory-based** reporting system:
    - for instance, a country seeking to demonstrate freedom from bovine spongiform encephalopathy (BSE) may collect laboratory results from BSE tests on neurological cases. The results may be all negative. This does not provide any information on what neurological diseases are present, but provides evidence that BSE is not present.
2. to **rule** out a disease in a **clinical negative reporting** system:
    - this can be used for diseases that show clearly evident clinical signs and that spread quickly, such as FMD in a naïve susceptible population.
    - for example, a system may be established, in which veterinarians complete a report after every farm or village visit, indicating that FMD *was not* present at the time of the visit. No special examination should be necessary, as, if it were present, it would normally be very easy to

identify by looking at the animals. The fact that the vet visited the farm, and did not notice any evidence of disease provides information that the disease was absent. (Note that there is a small chance that the vet was wrong, but this is the case with any type of testing or surveillance, and we will consider this problem later in this book). A surveillance system which collates large numbers of negative reports from a wide area is able to provide objective evidence that there are unlikely to be any animals with clinical signs of FMD.
    - documentation of such a clinical negative reporting system can provide valuable reassurance to trading partners about the continued freedom from disease of a particular zone, compartment or country.

Indirect indicators

Some surveillance systems do collect data on the disease or health status of animals directly, but take a more indirect approach:

- for instance, information provided by drug companies, distributors and feed supply stores on the sales of particular types of veterinary drugs and/or feeds can be used for indirect surveillance
- just like syndromic surveillance, changes in the patterns of drug sales and commercial feed sales are likely to be good indicators that there is a change in the pattern of disease. However, this does not say what the disease is.
    - Any observed changes must be followed up by a detailed investigation to assess if there is really an increase in disease, and if so, what is causing the disease.

Surveillance for indirect indicators of disease is often grouped together under syndromic surveillance. This approach is usually used to assist with the early detection of disease, and therefore the ideal indicators are those that change early in the disease process:

- for instance, the most common surveillance system used to detect disease is based on farmer reporting to a veterinarian when they have a disease problem. However, before the farmer calls the vet, they may try to treat the problem themselves.
    - If a new widespread problem affects a population, it may be possible to detect the problem earlier through the use of drug sales and/or commercial feed sales than by waiting for veterinary reports, which may only come some time later.
- in human disease surveillance, thermometer sales, and business sick-leave records have been found to be good early indicators of disease patterns in the population.

Indirect indicator surveillance is normally **active** surveillance, where the veterinary authorities establish a relationship with the holders of the data (e.g. drug suppliers),

and ask that updates on sales be provided at regular (e.g. daily or weekly) intervals for analysis.

Risk factors

Most surveillance seeks to collect information about disease or a disease-related state, including indirect surveillance which measures indicators of disease that occur early after the onset of disease.

Another approach to surveillance is not to measure disease at all, but to measure the risk factors that may be involved in *causing* the disease. This type of surveillance seeks to provide alerts before an outbreak of disease, so preventative measures can be put in place.

Example of risk factor surveillance:

- vector surveillance for vector-borne diseases
    - for bluetongue, the vector is the *Culicoides* biting midge. Insect trapping sites provide surveillance information on the presence or absence of the disease vector.
- risk factors for development of algal blooms (an aquatic animal surveillance example). Under certain conditions, algal blooms can develop which may produce toxins. These toxins can either kill farmed aquatic animals, or contaminate aquatic products making them unsafe for humans to eat.
    - Surveillance systems can be established to monitor sunlight, and water temperature to assess the risk of the development of the blooms.
    - Alternatively, the surveillance may directly measure the amount of algae present, and whether they are toxic or not.

External risk factors or factors not having a direct biological effect on the occurrence of disease in animals may also be considered in enhancing surveillance activity:

- in some regions, movement of animals during religious festivities from one area to another has resulted in the increase or resurgence of FMD outbreaks and other transboundary animal diseases.
- Data on prices and livestock movements may be used to predict times of increased risk and the location of potential new disease outbreaks.

How is surveillance information collected?

Characteristics of surveillance data collection systems

The main differences in the way surveillance data can be collected have been introduced on page 24: the *origin of the data* (active versus passive surveillance) or the *disease focus* (targeted versus general surveillance).

Two further related considerations when collecting surveillance information are the *population coverage* and the *representativeness* of the data.

Population coverage

Population coverage refers to the proportion of the population that is actually examined as part of the surveillance system:

- some surveillance is based on sampling from the population – only some animals are examined, while others are not
    - for instance, a sentinel herd system involves a relatively small number of herds, and a small number of animals from those herds which are tested or examined at regular intervals. Animals that are not in those herds are not examined at all, so we are using the herds as a sample of the population.
    - similarly, when we conduct a structured survey, we may randomly select a number of villages or farms, and then randomly select some animals from those villages or farms to test.
- the other approach is when all the animals in a population are part of the surveillance system. This is known as a *census* (examining all animals) as opposed to a *sample* (examining only a selected part of the population).
    - if our population of interest is all farmed pigs in the country, then a farmer reporting system covers the entire population, as every single pig in the country is examined (even if only very superficially) at a more or less regular interval. If a particular animal becomes diseased, there is a *chance* that that disease event will be captured by our surveillance system. The probability depends on many factors (the severity of the disease, the relationship between the farmer and the local vet, whether the local vet makes a report, and so on), but each pig, if they become sick, has a chance of being recorded in the system.
    - this is different to surveillance using sampling, where only those animals that are selected will end up in the surveillance system.

Representativeness

The representativeness of a surveillance system describes how well the information that we gather from the surveillance system describes the population of interest:

- if the characteristics of the animals in our surveillance system (for instance, the percent of animals with protective antibody titres) is about the same as in the source population, the system is *representative* of the population.
- if there is a difference, (for instance, in our surveillance system, we appear to have 90% of animals with protective antibodies, but in the source population we only have 60%), the surveillance system is not representative, and is called *biased*

- bias is the difference between the real value in the population and the value we measure through our surveillance.

In many cases, bias due to a non-representative surveillance system can cause a very big problem.

For instance, consider abattoir surveillance to assess the level of contagious bovine pleuropneumonia (CBPP) in a population:

- this system uses a *sample* of the population (our population of interest is all farmed cattle, but our surveillance only examines those that go through the abattoir).
- animals infected with CBPP are likely to be sick or to die on the farm. An animal with the disease is much less likely to be sent to the abattoir than a healthy animal.
- as a result, the proportion of cattle with CBPP in the abattoir is likely to be much lower than the proportion on the farms. This type of surveillance is, therefore, biased.
- as the surveillance system is likely to detect a lower proportion of animals than are truly infected, it is called *negatively biased*.

The meat inspection system in some developing countries is not yet as developed as in other countries. This means that there is more common for sick animals to enter an abattoir than in countries where well developed controls are in place. This makes abattoir surveillance in some less developed countries more useful for detecting clinical disease.

When biases are present, making animal health management policy decisions on the basis of biased information could be very dangerous. If this information was being used to monitor the progress of a control program, or to prioritise spending on future disease control programs, the decisions that are made are likely to be wrong and have a negative effect on the health of the population.

For example, the level of disease may be apparently low, so no action will be taken, when, in reality, the true level of disease may be high.

Surveillance systems providing comprehensive coverage of the population are generally more likely to be representative. However, if the probability that some animals are recorded in the surveillance system is different to some other groups of animals, these systems can also be non-representative.

For instance, a surveillance system for brucellosis may be based on farmer reporting of abortions or arthritis:

- if a control program that involves modifying the management systems around calving to limit the spread of the disease is in place, those farms that adopt good management are less likely to have the disease.
- on the other hand, farms that do not choose to use these good management practices may have higher levels of disease. However, farmers with poor management may also be less likely to report disease than farmers with good management.
    - as a result, the disease rates may be higher, but the reporting rates lower from farms with poor management compared to those with good management.
- the outcome is that, even with a system in which every affected animal has a *chance* of being reported, differences in disease and reporting probabilities can result in a bias – in this case making the total level of disease appear lower than it actually is.

These examples have shown how surveillance that produces biased results can lead to poor decision making when an accurate assessment of the level of disease is required from the surveillance system. Note that these systems typically produce results in terms of a proportion:

- the percentage of animals with CBPP
- the percentage of animals with protective antibody titres against FMD.

In other words, if you are making decisions that are based on data expressed in the form of a proportion or percentage (such as evaluating the progress of a disease control program), then it will be important that the surveillance system avoids bias:

- approaches to avoiding bias are discussed later in this book.

However, in some circumstances, biased or non-representative surveillance can actually be a good thing:

- surveillance systems that aim to detect disease (such as early warning systems) or demonstrate freedom from disease (e.g. for trade or zoning) can be more efficient when they are biased.
- these types of surveillance systems do not aim to measure a proportion, but instead aim to detect at least one infected animal.

Use of biased or non-representative surveillance

When demonstrating freedom from disease or infection, the system must be able to detect any diseased or infected animals as efficiently as possible. If the system is very good at detecting diseased animals, and still fails to detect any, then we can be very confident that no diseased animals are present:

- the output of such systems is therefore not a proportion, but a yes/no answer:

    - yes: disease was detected
    - no: disease was not detected
- the confidence that we have in this answer depends on how good our system is at detecting disease.
    - this is measured by the *sensitivity* of the surveillance system.

Surveillance system sensitivity

The sensitivity of the surveillance system is the probability that, if disease is present in the population (at a specified level), the surveillance system will be able find it.

There are three main ways to make a surveillance system more sensitive:

1. examine more animals
    - if a very large number of animals are examined, the chances of finding disease, if it is present, increase.
2. improving the probability of detecting disease, if it is present
    - for instance, if the surveillance system depends on farmer reporting, it can be made more sensitive by using extension or public awareness campaigns which increase the chance that a farmer will report disease if he or she sees it.
3. use *risk-based* surveillance
    - this approach focuses the surveillance on groups within the population that are at a higher risk of having the disease than the rest of the population
    - by examining the high-risk animals, we are more likely to detect the disease if it is present, than if we examined animals at lower risk.
    - risk-based surveillance is sometimes called 'targeted ' surveillance; however, this may be easily confused with surveillance targeted at a specific disease (as described in the last chapter), so the term risk-based surveillance is preferred.

Risk-based surveillance

Risk-based surveillance is structured so that it intentionally introduces a *positive bias*. This means that animals that have the disease or infection are more likely to be in our surveillance system than would be achieved in a representative system:

- as a result, given a fixed number of animals examined, the chance of finding the disease is higher (better sensitivity)
- alternatively, to achieve a fixed target sensitivity, fewer animals may be examined (resulting in cost savings).

Risk-based surveillance is a valuable tool for increasing the efficiency of surveillance when aiming to detect disease or demonstrate freedom from disease:

- however, it depends on a good understanding of the risk factors related to the disease.

In practice, some easily-identifiable characteristic is used to divide the population up into two or more groups, with different risk of having the disease (if the disease is present). Three types of characteristics can be used to divide the population:

1. causal factors **for** the disease:
    - these are factors that are involved in causing the disease
    - for instance, farms that import many animals are at a higher risk of having disease than closed farms, as the imports may introduce (and therefore cause) the disease.
2. factors that are caused **by** the disease:
    - detecting Johne's disease (caused by *Mycobacterium avium* subspecies *paratuberculosis*) on a farm is more efficient if animals that have diarrhoea are tested rather than animals that do not have diarrhoea, as Johne's disease causes diarrhoea in its clinical stage.
3. non-causal factors that are associated with either of the above:
    - selecting farms with small numbers of animals may be a simple approach to identifying risk groups
    - small farms are normally not commercial, and the farmers are less likely to be experienced, and therefore have poor management skills. The poor management may the cause of the disease, but the number of animals is related to poor management. Obviously some small farms may have good management, but the aim of risk-based surveillance is to divide the population into groups in which the *average* risk of disease is different, using some easily available identifier.
    - it may be much easier to find information on farm size than directly find out how good every farmer's management skills are, so this may be an appropriate factor upon which to base the surveillance.

The choice of factor (or factors) to use in risk-based surveillance is very important. If our understanding of the risk is not good, we may choose a factor which provides a group that is at *lower* risk of disease than the other group:

- for instance, if we were doing surveillance for bovine spongiform encephalopathy (BSE or Mad Cow Disease), small farms may use very few food additives when feeding their cattle, whereas larger farms may routinely use meat and bone meal, a key risk factor for BSE. If our assumption about risk is incorrect, then our surveillance system may be *negatively biased* instead of positively biased, which means that we have a lower chance of detecting disease than if we had a representative system, and our sensitivity is decreased.
- therefore,it is always advisable to use factors which have been demonstrated through research to be associated with a higher risk of having the disease.

The example described above of abattoir surveillance provides an illustration of a negatively biased system, but one which could still be of value:

- if, instead of aiming to evaluate progress in a disease control program for CBPP, we had completed the program and were aiming to demonstrate freedom from disease, abattoir surveillance may still be of value, even if it is less sensitive than alternative representative systems.
- this is because, as passive surveillance, the cost of the surveillance is very low, and large numbers are processed.

General Guidelines for Collecting Surveillance Information

As there are so many different aspects to surveillance, and so many different approaches that can be taken, it may be useful to provide some general guidance on situations in which different systems may be of value:

Representative surveillance:

- should be used when aiming to measuring the level of disease, describe the distribution of disease, or assess the progress of a control program, i.e. any type of surveillance that produces a result that is a proportion or similar measure of disease
- may also be used when aiming to demonstrate freedom from disease or in early warning systems, but it can be much less efficient than risk-based surveillance in these situations.

Risk-based surveillance:

- should be used where possible when demonstrating freedom from disease or in early warning systems where the epidemiology of disease is already known
- should be avoided when measuring disease, as significant biases are likely
- not practical for emerging diseases as epidemiology of the said disease is still unknown.

Targeted surveillance (for a specific disease):

- should be used when the surveillance system is interested in learning about a single disease (or small number of diseases)
- tests used for targeted surveillance are often more sensitive and specific than for general surveillance
- not suitable for surveillance when the disease of interest is not known or clear (e.g. for systems designed to detect emerging or new diseases).

General surveillance:

- this is the only way to detect new or unknown diseases (targeted surveillance cannot)
- may be quite sensitive (system able to pick up any disease), but follow-up testing or investigation is required to determine exactly what disease has been detected.

Active surveillance:

- should be used when:
    - there is a need for surveillance data of a known quality that is not otherwise available
    - when the resources are available to collect it
- enables surveillance activity to be designed to provide exactly the data that is needed to answer key questions
- is often expensive
- due to the expense, often is not able to process very large numbers of animals
- if properly designed and implemented, can avoid bias and get representative data

Passive surveillance:

- is usually much cheaper than active surveillance
- as the veterinary services have little control over the nature or process of data collection, the results may not be able to answer the key questions
- may be much more rapid, as data already exists
- public education specifically farmer education could improve and add value to passive surveillance.

Comprehensive population coverage:

- usually only possible with passive surveillance systems (e.g. farmer disease reporting)
- may be possible with comprehensive disease control or eradication programs (testing every animal on every farm in the country)
- the large number of animals processed may provide improved sensitivity in systems to detect disease (but not if the detection system has poor sensitivity such as when farmers are very unlikely to report disease)
- large numbers of animals may make biases less when measuring disease levels, (but there can still be important biases).

Sample-based surveillance:

- more common
- analysis needs to take sampling into account and be aware of any biases.

Deciding on an appropriate surveillance strategy

The process of deciding on the most appropriate surveillance strategy is summarized below. More detail is given in later chapters.

- What is the objective of doing surveillance?
- What information do I need to know for animal health management, and to make appropriate decisions?
    - How important are these decisions? This is used to help prioritise surveillance activities.
- What are the possible sources of this information?
    - Is there existing information that will help answer the questions?
    - If so:
        - Is it accessible?
        - How much would it cost to get it?
        - Do we have the resources go get it?
        - What is the quality of the available data?
            - What is the coverage?
                - Does it cover the right species?
                - Does it cover the right production systems?
                - Is it from a relevant time period?
            - Is the data biased?
                - If so, what are the biases
                - Will these biases mean that the data is less valuable or more valuable (e.g. for risk-based surveillance)?
            - Will the data help answer the question?
    - If there is no data available, or the data is not good enough:
        - What are the options for collecting new data?
        - What are the quality standards for any new data collected?
            - Should it be representative or risk-based?
            - What disease detection system (tests) should we use?
                - Targeted on a specific disease?
                - General surveillance?
            - How often does the data need to be collected?
            - What should the coverage be?
            - How much data is needed to answer the questions?
        - How much will these options cost?

Activities

1. In groups, choose three significant policy issues/decisions relevant to your work.
2. Define the animal health questions that would help make good decisions.

3. Answer the example questions in the list above in reference to each of your policy issues, in order to determine the appropriate type of surveillance to support each issue.
4. Describe the strengths and weaknesses of each of the surveillance systems you have proposed.

Use and interpretation of tests

Surveillance and tests

Learning Objectives

After studying this chapter you should be able to:

- ☐ List the key important characteristics of tests
- ☐ Define sensitivity and specificity, and calculate these values given appropriate data
- ☐ Explain the difference between the use of tests for screening and diagnosis
- ☐ Understand the benefits an limitations of combining multiple tests in a surveillance system
- ☐ Describe different approaches to dealing with the problem of imperfect tests in surveillance

A test is broadly defined as any procedure that aims to divides a population into two groups:

1. **with** the characteristic of interest (disease, infection, presence of antibodies etc), and
2. **without** the characteristic of interest.

All tests may make errors in this classification, but to qualify as a test, the procedure should classify animals at least more accurately than a purely random procedure (such as tossing a coin).

The two types of **errors** that a test can make are:

1. false positive:
    - falsely identifying an animal without the characteristic as having the characteristic
2. false negative:
    - falsely identifying an animal that does have the characteristic as not having it.

The **validity** of a test is described by the probability that it will get the classification correct. Validity is expressed in terms of *sensitivity*, and *specificity*.

- sensitivity
  - the probability that a positive animal will be identified as positive by the test (this is 1 – false negative rate)
  - this describes how well the test performs for truly positive (e.g. infected) animals
- specificity
  - the probability that a negative animal will be correctly identified as negative by the test (this is 1 – false positive rate)
  - this describes how well the test performs for truly negative (e.g. healthy) animals.

These ideas are illustrated in the following diagram:

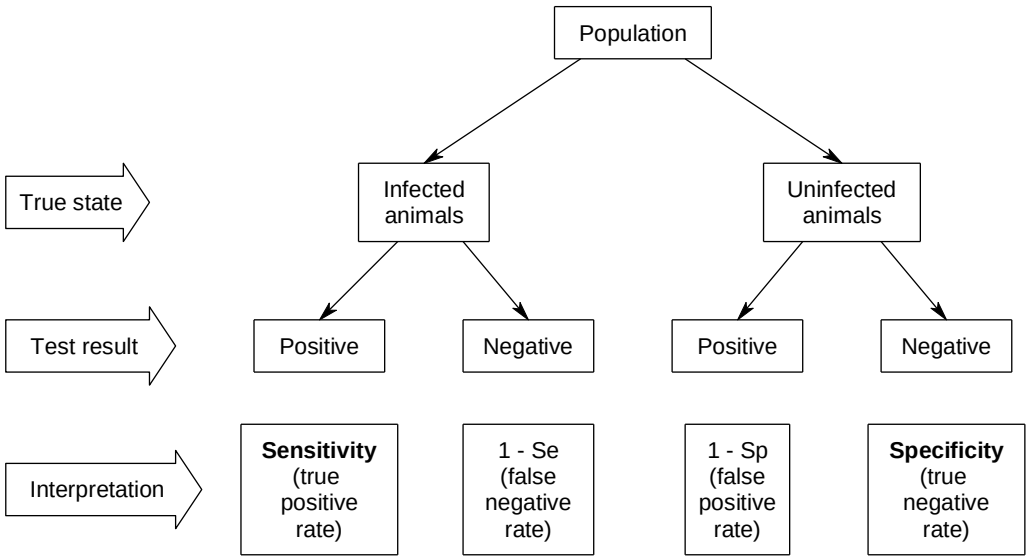


Figure 5: Sensitivity and specificity

Sensitivity and specificity can be calculated using studies in which the test is applied to animals whose true status is known. The data is usually arranged in a two-by-two table as shown below.

		True Status		
		Positive	Negative	Total
Test Result	Positive	a	b	a + b
	Negative	c	d	c + d
	Total	a + c	b + d	a + b + c + d

The sensitivity is the number of correct results (true positives), **a**, divided by the total number of truly positive animals, **a + c**.

The specificity is the number of correct results (true negatives), **d**, divided by the total number of truly negative animals, **b + d**.

For example, if a new test were applied to 100 animals, made up of 60 healthy animals and 40 infected animals, the following results may be obtained:

		True Status		
		Positive	Negative	Total
Test Result	Positive	36	10	46
	Negative	4	50	54
	Total	40	60	100

The sensitivity of this test is 36/40 = 90%.

The specificity of this test is 50/60 = 83.3%

If the true status of animals is not known, this approach cannot be used. New modelling techniques are available to estimate sensitivity and specificity when the true status of animals is not known. These techniques rely on the use of more than one test in a number of different populations. Detailed consideration of these techniques is beyond the scope of this manual.

Non-laboratory tests

While we often think of laboratory procedures when we talk about tests, any other procedure that meets the above criteria is also a test. Examples include:

- clinical examination
- meat inspection
- examination of food consumption records in a grower shed for pigs.

By considering such a wide range of activities as tests, we are offered a very wide range of options when designing a surveillance program. In order to help us decide what tests we should use for a particular type of surveillance, we need to understand the **characteristics** of the different tests. The key characteristics are:

- sensitivity
    - the ability to pick up cases if they exist
- specificity
    - how well it avoids false positives
- cost

    - there is often a relationship between cost and validity (sensitivity and specificity)
- speed
    - this is partly related to cost
- practicality
    - is the test able to be simply performed?
    - is it safe?
    - are adequately trained staff available?
- current adoption
    - how widely is the test used at the moment?

The choice of the right test to use is based on a balance between these characteristics, but in balancing some of the relationships and compromises should be first understood.

Avoiding errors

It is obvious that any surveillance will be better if the test used makes as few errors as possible:

- this means that both the sensitivity and the specificity should be as high as possible
- often, the consideration of what test to use stops at this point, and it is concluded that the best test is the one with the best sensitivity and specificity.
    - *this is not always the case*.

Getting large numbers

Surveillance is not the same as making a diagnosis in an individual animal.

Surveillance involves **screening** rather than diagnosis:

- *screening* is the use of a test on large numbers of healthy animals for classification purposes to find out information about the population
- *diagnosis*, in contrast, uses a test on an individual sick animal, to find out about the individual animal.

When dealing at the **population** level, a number of factors play a role in determining how good the surveillance is, and these are discussed later in this book. However, for all types of surveillance, increasing the **number** of animals tested is an effective way of increasing the quality of the conclusions:

- when measuring the level of disease, larger sample sizes will produce greater precision, and if the sample size is large compared to the population, it will even start to decrease any biases
- when demonstrating freedom from disease, the overall sensitivity of the surveillance increases directly with the number of animals tested

The effect of sample size is more important than the effect of the individual animal test sensitivity. As a rough rule of thumb, therefore, surveillance involving large numbers of animals is often more useful than surveillance with small numbers:

- as noted, tests with high sensitivity and specificity are often more expensive, which limits the number of animals that can be tested
- it may therefore often be warranted to use tests of lower sensitivity and/or specificity, because
    - they may be much cheaper
    - they may therefore be used on a very large number of animals.

For instance, when detecting incursions of exotic disease, there may be two options:

1. conduct regular surveys to collect blood and do laboratory tests for antibodies to the disease
    - the test may be an ELISA with very high sensitivity and specificity
2. use clinical surveillance and the farmer reporting system to detect the disease
    - the test is farmer examination of the animals, which has moderate sensitivity and very low specificity.

Most early detection systems are based primarily on farmer reporting, despite the poor 'test' performance, because:

- surveys are expensive and are only able to test a tiny proportion of the population
- farmer reporting systems are cheap, and as a result, most of the animals in the country can be 'tested' (examined by their owners) almost every day.

The sensitivity of farmer detection also depends on their willingness to report any disease they notice. This is strongly influenced by factors such as awareness and incentives. Early detection systems can be significantly improved by ensuring that disincentives (such as the fear of destruction of animals without compensation) are removed.

Combination of tests

Fortunately, we do not need to depend just on the results of a single test.

In the example above, a country would not be considered infected with an exotic disease just because a farmer found a sick animal and reported it. The first test (examination of the animal by the farmer) is quickly followed by a series of other tests:

- clinical examination by a veterinarian
- laboratory tests for antibodies
- confirmatory laboratory tests for the disease agent.

The combination of multiple tests allows us to avoid certain mistakes. In this case, we want to be sure that we are not falsely identifying an exotic disease, so we are trying to increase the specificity and decrease the chance of a false positive. The animal would only be considered positive if all of the following occur:

1. the farmer thought there was a problem
2. the veterinarian also thought there was a problem
3. the first (antibody) laboratory test gave a positive response
4. the confirmatory (agent) laboratory test gave a positive response.

After all these tests, we can be very certain that, if the result of all of them is positive, then the animal is truly infected.

There is always a **trade-off** when combining tests:

- in the above example, we increased specificity
    - with each extra test, the chance of making a false positive decreased
- however, this same process results in a *decrease* in sensitivity
    - the animal would be called negative if, at any stage, there was a negative result in any of the four tests
    - as each test has a chance of getting a false negative result, the chances of a false negative result increase with each extra test used.

In this case, in order to achieve high specificity, we need to sacrifice sensitivity. This is because of our interpretation of the results – the animal is only positive if it tests positive to all the tests.

Using a **different interpretation** would change the overall test characteristics. If we consider that the animal is only negative if it is negative to all tests, the result would be to *increase* the sensitivity, but *decrease* the specificity. Formulae for calculating the combined sensitivity and specificity when using multiple tests and different interpretations are included in the appendix.

Dealing with imperfect tests

All tests are imperfect, and have a chance of getting either false positive or false negative results. This poses different types of problems, depending on the **nature** of the surveillance.

Measuring the level of disease

When measuring the level of disease in an endemic situation, the true status of individual animals is not too important:

- the objective is to measure the true level of disease for decision making

- however, false positives and false negatives mean that the answer obtained from the surveillance (the apparent prevalence) is likely to be different from the real answer (the true prevalence), and this difference (bias) can be large
- if the sensitivity and specificity of the test are known, or can be estimated, then it is possible to adjust the apparent prevalence to calculate the true prevalence.

The formula for calculating true prevalence based on apparent prevalence is provided in the appendix.

Detecting disease or demonstrating freedom

Imperfect tests are a greater problem when trying to demonstrate freedom from disease or for early warning systems. For example, a single positive case:

- means that the country is not free
- can have a major impact on trade
- might result in the launch of an emergency response.

False negatives at the individual animal level due to imperfect sensitivity potentially are very dangerous, as they provide an opportunity for the disease to spread undetected:

- if a positive case of an emergency disease is missed today, and the disease does spread, then it will almost certainly be picked up in the near future as more cases appear
- however, a delay in detection is a potential disaster, as it can dramatically increase control and eradication costs
- sensitivity should always be high to avoid this problem, but there is always a risk that it will occur.

False positives present a different dilemma, as veterinary authorities are very reluctant to declare that they have an exotic disease when that declaration may be false. The potential cost to trade and costs due to the emergency response are enormous. As a result, it is necessary to consider what actions should be taken before positive cases are found.

Strategy for handling positive results

There are two main approaches to dealing with positive results when aiming to demonstrate freedom from disease.

1. **Statistical approach**

This approach involves **statistical reasoning**.

Consider this example:

- a country has eradicated a disease, and is conducting sero-surveillance to demonstrate that the disease is truly gone
- the test used is an ELISA and the specificity of the test is known to be 98%, while the sensitivity is 95%
- such surveys routinely test thousands of animals, and one should expect a false positive rate of 2% (1 – Sp, or 1 – 98%)

How is it possible to determine if these positive results represent true positives or false positives?

Response:

Step 1: Analyse the likely false positive and true positive rates under two different assumptions:

- if the population were free
    - you would expect about 2% of positive cases
- if the population were infected, and the disease were highly contagious, one may use a *design prevalence* of, say, 5% (see page 143)
    - this means that we assume that the prevalence of disease, if infected, would be 5% or greater
    - calculate the expected number of positive results from an infected population as follows:

Expected prevalence $= (P^{*} \times Se) + [(1-P^{*}) \times (1-Sp)]$

$= (5\% \times 95\%) + [(1-5\%) \times (1-2\%)]$

$= 6.65\%$

In words this formula can be expressed as:

> The expected proportion of positive results is equal to:
>
> - the number of positive animals times the proportion of those that give a positive result (the sensitivity), plus
> - the number of negative animals times the proportion of those that give a positive result (one minus the specificity)

If the observed number of positive results is about 2%, and this is **statistically different** from 6.65% (depending on the sample size), then we may conclude that the positive results are false positives. This calculation is automated in the FreeCalc software contained on the accompanying CD.

Step 2: Justify this conclusion on biological grounds:

- false positive results to an ELISA test should be randomly distributed in the population, and should have optical density results close to the cut-off value
    - all the positive results should be examined to check that they are all 'low-positives' close to the cut-off value
- the geographic distribution of the results should also be examined, to check if they are randomly distributed amongst the sampled population as would be expected if the disease was not present
    - any sign of clustering could indicate that disease was still present
- if both of these criteria are met, it may be possible to argue that, despite positive test results, the surveillance has provided enough evidence to demonstrate that the population is free from disease.

2. **Combined testing approach**

The other, more commonly used, approach is to follow-up every positive test result:

- the principle here is to use a combination of tests, interpreted in series, to increase the specificity to nearly 100%
- using a combination of tests each with good specificity is able to achieve this, and almost (but not completely) remove the risk of concluding that an animal is infected when, in reality, it is not infected.

There are two problems with this approach:

1. it is expensive and time consuming
    - the follow-up testing often involves returning to the herd of origin, and retesting all animals, and/or conducting bioassays to determine if the disease agent is present
2. every new test that is used to increase the specificity of the surveillance system will result in a decrease in the sensitivity, which must be taken into account when analysing the surveillance data.

Any follow-up testing regime must be decided and documented in advance, and the resultant overall test combination sensitivity and specificity calculated:

- the reason for this is to avoid ad-hoc continuous re-testing of suspect samples
- it is well recognised that if you test a positive sample enough times, eventually you have a good chance of getting back a negative result
    - this simply reflects the decreasing sensitivity produced by repeated testing
- the resultant overall test combination sensitivity and specificity should be calculated before any testing is conducted
    - the overall sensitivity of the surveillance will be decreased due to the decrease in individual animal sensitivity

- the combination sensitivity and specificity values should be used to describe the system, even if no positives are found and the (follow-up) combination testing is not actually used.

Requirements for Effective Surveillance

Learning Objectives

After studying this chapter you should be able to:

- ☐ Develop a comprehensive surveillance plan, including
  - the objectives and scope of the surveillance,
  - a data collection plan
  - a resource plan
  - details on the analysis to be performed
  - a plan for reporting and distributing the results of analysis
  - a clear understanding of the different impacts the results of the surveillance may have on disease control decisions

This section provides **general** guidance on the requirements for effective surveillance. More specific information on different approaches to surveillance is provided in the following chapters.

While much surveillance evolves over time and may change in response to changing needs, in order to be effective, it should still be clearly planned and understood:

- if certain aspects of a surveillance system are not understood, it is very unlikely that they can be effective
- by understanding the way a system works, it is then possible to identify weaknesses and correct problems
- development of a **surveillance plan** is an important step in ensuring that the aims of and technical operation of the surveillance are clearly thought out and well understood. A surveillance plan should address all the items listed in this chapter.

Objectives and scope

In order to be effective, there should be a clear understanding of the objectives of the system and the scope of the surveillance.

General purpose of surveillance

Why is the surveillance being done? This can usually be classified into one (or sometimes several) of the following categories:

- detect disease
- demonstrate freedom from disease
- describe disease distribution
- assess control program progress

Context

What is the general situation that means that the surveillance is necessary?

For example:

- supporting export trade to key trading partners by providing evidence for free zones
- supporting a disease eradication program
- prioritising endemic disease control activities

Specific purpose

This can often best be addressed by framing the question or questions that the surveillance will serve to answer.

For example:

- is a defined free zone free?
    - what level of evidence can we provide for its free status?

Disease(s) of interest

Identify what disease or diseases are the focus of the surveillance activity.

Examples:

- highly pathogenic avian influenza
- emerging or exotic diseases
- endemic diseases

Planned use of data

How will the data collected be used?

- will it be used to support decisions?

    - this should normally the case, even if the decision is that no action or change is required.
- if data is not used for decision making, why is it being collected?

What are the expected benefits of the surveillance?

- do the economic benefits warrant the cost of the surveillance?
- are there other important benefits?

Data collection

Populations

What is the population of interest? This can be determined by referring to the key questions that the surveillance is intended to answer:

- for instance, if the surveillance is concerned with food safety, then the population may be all slaughter animals, and abattoir surveillance is appropriate.

What is the population that is actually under surveillance?

- this may be different from the population of interest, and lead to potential biases.

How well is the population covered by the surveillance?

- is the entire population examined in some form or other, or is it only a sample?
    - if it is a sample, is the sample representative (such as one selected using random sampling), or is it selected in some other way?
    - if it is biased, is the bias positive (diseased animals are more likely to be in the sample than health animals), or negative (diseased animals are underrepresented)?

Surveillance activity

What surveillance activity is used to collect the data?

Where is the original data generated, who generates it, what are the data flow pathways?

Are multiple activities used?

Disease detection

What disease detection mechanism (or test) is used?

Is the performance of any tests used quantitatively understood?

- what are the limitations of these tests?

Standardisation

Are there standardised operating procedures in the surveillance (SOPs) so that everybody involved is doing the same thing, and knows exactly how it is meant to be done?

- selection of units (farms, animals, samples, data)
- tests used
- interpretation of results
- analysis of data

Resources

What resources are available?

- money
- staff
- transport
- communication
- laboratory
- other equipment
- data management and analysis

Data quality assurance

Are there any measures in place to allow the quality of surveillance data to be verified?

- HACCP (hazard analysis and critical control points)
- auditing systems?

Data analysis

How is the data analysed?

What are the key figures that are generated by the analysis?

Are the analytical methodologies appropriate for the type of data?

- does the structure of the data violate any of the statistical assumptions?
- are there biases in the results that could influence the interpretation of the results?

Are analytical systems automated to ensure that they are rapid and repeatable (avoiding delays in processing and human error)?

Data reporting and decision making

What happens to the results of the surveillance?

How it is used?

- if it is used for decision making, is it provided to decision makers in a form that is appropriate to make their job easier?

Are there systems in place to assist respond to the surveillance findings?

- if certain events, diseases, or situations are detected through surveillance, are there plans as to how to respond?
    - for new incursions of disease, are there emergency response contingency plans?
    - if measuring the level of endemic disease, are there identified 'alert levels' that indicate that action should be taken if there is a change in the level or distribution of the disease?

Approaches to Surveillance

The following table lists a number of example approaches to surveillance for different objectives.

Table 2: Examples of approaches to surveillance for different objectives.

Objective		Potential data sources
Disease that are absent	demonstrate freedom	• farmer reporting • abattoir • negative reporting
	early detection	• farmer reporting
Diseases that are present	measure level and distribution of disease	• structured survey
	assess progress of control programs	• control activities • abattoir • structured survey

Activities

In 2004, Lao PDR reported an outbreak of highly pathogenic avian influenza occurring in Vientiane province and capital.

The **question** was whether the outbreaks were just in these two areas or the only ones *reported* because of its proximity to the government capital:

- a surveillance activity was therefore designed to look for the disease in 18 provinces
- the objective was to detect disease and know its distribution
- structured survey was designed and conducted focusing on farmer interviews
- reports from village animal health workers were also assessed.

Practical Implementation of Surveillance Systems

Learning Objectives

After studying this chapter you should be able to:

- ☐ List a range of different approaches to surveillance
- ☐ Explain when each approach is useful and when it is not
- ☐ Describe the normal operation of each approach
- ☐ List common problems and identify practical approaches to overcoming these problems

You should be able to describe at least the following systems:

- ☐ Farmer reporting system
- ☐ Abattoir surveillance system
- ☐ Veterinary negative reporting system
- ☐ Sentinel herds or flocks
- ☐ Representative and targeted surveys
- ☐ Syndromic surveillance systems

This section:

- considers a number of common approaches to surveillance
- describes their typical operation
- examines common problems and possible solutions.

There are many approaches to surveillance, and this list is not intended to be exhaustive. It simply aims to provide guidance and stimulate ideas.

Farmer reporting system

Farmer reporting systems describe the surveillance that is achieved when a farmer identifies that they have some sick animals, and contacts a veterinarian for help.

Farmer reporting systems are:

- the most common and probably the most important form of surveillance in any country
- examples of passive surveillance, as the reason the farmer contacts the veterinarian is not for surveillance, but in order to get help with the sick animals
- also examples of general surveillance, as they are able to identify a wide range of diseases.

Farmer reporting systems have a number of key advantages:

- the coverage of the animal population is usually very good as the person responsible for identifying disease is the farmer
- most animals in the population are seen by their owners relatively frequently
    - this contrasts with, for example, a survey, where only a very small proportion of the population is examined
- the system is relatively inexpensive
    - farmers need to contact the veterinarian anyway, so the main extra cost is related to collecting the information for surveillance purposes.

Farmer reporting systems are often the means by which new diseases are first discovered, either incursions of exotic diseases or emerging diseases, because:

- there is high coverage of the population
- it is general surveillance capable of detecting any disease.

Farmer reporting systems therefore play a very important role in any national surveillance system. These systems are far from perfect however, due to:

- farmers not observing their animals
- farmers not recognising signs of disease
- farmers being afraid to report because of the fear of negative consequences
- farmers being unable to report if they are remote
- failure of the reporting system within the veterinary services to correctly register the disease or diagnose the disease.

Efforts to address these limitations can significantly improve early detection of diseases.

Description

There are many variations in the detailed operation of farmer disease reporting systems, but a typical system may operate as described below:

1. an animal gets sick, and is noticed by the farmer:
    - the chances that the farmer notices the animal depend on the signs that the sick animal is showing
        - if the signs are more spectacular (such as sudden death, unusual neurological signs, or large visible lesions) they will be easier for a farmer to notice
    - similarly, if more than one animal is affected, it is easier to notice
    - sometimes, the problem the farmer experiences may not be associated with clinical signs at all
        - subclinical disease at a herd level may cause production losses that are noticed by the farmer, prompting them to call the veterinarian (e.g. nutritional deficiencies or mastitis).
2. the farmer contacts somebody about the sick animal or animals:
    - there may be a chain of different people that are contacted, but ultimately, somebody from the official veterinary services needs to know about the case if the information is to be used for surveillance
    - the simplest case is when the farmer contacts the local government veterinary officer directly
    - alternatively, they may contact a private veterinarian, who then contacts a government veterinarian
    - there may be a number of other steps, such as contacting neighbours or the village head for assistance, or the local animal health worker.
3. information about the case is then recorded:
    - normally this is done by the local government veterinarian but can happen at other stages
    - information may be recorded in a number of ways, but normally this is done using a standard paper form.
4. the written disease report is then passed through a reporting hierarchy:
    - if it was filled out by the local village animal health worker, it would then be passed to the district veterinary office
        - the information may then be passed from the district to the provincial office, then perhaps to a regional office, before it arrives at the national office
    - at each stage, the information in the disease report may be analysed, summarised, or transformed into a different format
    - one common approach is that the reports are collated at the district level, and a summary report indicating the number of cases of different diseases is sent to the provincial office each month.

    - the provincial offices then combine all district reports into a single provincial summary of the number of cases, which is then sent to the national office, who collate all the provincial reports.

Once surveillance data has been collected at the national level it is available for use:

- routine use of farmer reporting data often includes generating annual reports with figures on the number of cases of different disease reported each year, as well as reports to meet international reporting obligations.

Diagnostic laboratories are often seen as alternative sources of surveillance data:

- however, the process by which samples arrive at the laboratory is basically the same as a farmer reporting system - the farmer has to notice that an animal is sick and seek veterinary help
- sometimes no distinct written report is generated in the field, but a diagnostic specimen is collected and sent to the laboratory
- data from the laboratories is then summarised and sent to the provincial or national offices for reporting, either linked to field reports or independent of them.

Objectives of farmer reporting systems

In order to determine how well farmer reporting systems are working, and if any improvements can be made, it is important to first consider the **objectives** of the system and what is required to meet these objectives.

Possible objectives include:

- early warning
- proof of freedom from disease
- describe current disease status or changes in the distribution or amount of disease.

Early warning

As mentioned above, farmer reporting systems are a form of general surveillance, and are therefore able to detect a wide range of diseases, including previously unrecognised or exotic diseases.

They are therefore important as part of an early warning system, to identify the occurrence of a newly emerging disease, or an exotic disease.

In order to meet this objective, the main requirements of the system are that it is:

- rapid

    - once a problem is recognised in the field, this information needs to be given to decision makers as quickly as possible (normally at the national level), so that an effective disease response can be launched as quickly as possible.
- comprehensive
    - emerging or exotic diseases can arise anywhere (even though some areas may be at higher risk than others)
    - the aim is to detect and response to the outbreak before any significant spread has occurred
    - to do this, it should be detected on the first farm that is affected
    - this means that every farm in every part of the country should be under surveillance
    - if, for instance, only 50% of farms report disease problems, then there is a fair chance that the problem could appear on a farm that does not report, and therefore won't be detected until it spreads to a farm that does report
    - there are even greater problems if the level of reporting varies by area. If there is an area with very low reporting rates (e.g. a remote area with poor communications), the disease may spread widely in that area without being reported, and only be reported when it moves into an area with better reporting rates.
- accurate
    - the information that is required for a rapid response is that there is a potentially important disease problem in a particular area
    - in order to distinguish whether a problem is potentially important, a diagnosis is normally necessary
    - sometimes a precise diagnosis is not possible, such as when there is a new emerging disease that has never been described before
        - the important thing in this case is that common and unimportant diseases are accurately excluded from the diagnosis
    - it follows that the options for a diagnosis of a disease problem are:
        - it is a normal endemic disease that does not require an emergency response
        - it is a recognised exotic disease that does require an emergency response
        - it is an unknown disease for which no diagnosis can be made. It may or may not require an emergency response.
    - if these three diagnostic options get mixed, it can result in serious problems:
        - if an emergency disease is mistakenly diagnosed as a normal endemic disease, no response will be made and the disease will be able to spread with no control.

Farmer reporting systems are often amongst the best available tools for early warning and early detection of new diseases, due to their extensive coverage. Others less common systems can also provide valuable information, such as syndromic surveillance or indirect surveillance.

Proof of freedom from disease

If one of the objectives of surveillance is to demonstrate that a particular disease is not present, a farmer reporting system can contribute evidence.

The fact that a disease has not been reported through the system makes it *more likely* that the disease is not present at all. It doesn't provide absolute proof (nothing can), but the more sensitive the farmer reporting system, the stronger the evidence of freedom. A weak farmer reporting system may provide very little evidence at all.

Factors that make this evidence stronger include:

- comprehensive coverage
    - if the surveillance system only receives reports from a proportion of farms, then it is possible that the disease exists on a non-reporting farm
- nature of the disease
    - a rapidly spreading disease with clear clinical signs and an important impact on production (including death) is much more likely to be reported than a disease that develops very slowly, or has only subtle effects or no clinical signs
- effective reporting system
    - when one depends on an absence of information to provide evidence for absence of disease, it is important to be sure that, if the disease were present, there is a high chance that this would result in a positive report
    - even if a farmer identified a disease problem, there has to be a good chance that the farmer would get a veterinarian to look at the animal, that the veterinarian would report it to the provincial authorities and that the province would pass this information to the national authorities
- effective diagnostic system (relates to the previous point)
    - no matter how good the reporting system, a country can only indicate that it has an outbreak of an exotic disease if there is a laboratory that is capable of making a definitive diagnosis of that disease
    - if no tests are available, or the tests that are being used have very poor sensitivity, then, even if a sample is received, there is little chance of arriving at a positive diagnosis for the disease.

Describe current disease status or changes in the distribution and amount of disease

This objective requires measures of disease prevalence or incidence in different areas.

In order to meet this objective a farmer reporting system should be:

- unbiased
    - bias is when the estimates of the level of disease that are provided by the surveillance system are not the same as the true level of disease in the population
    - this normally happens when there is a factor that influences the probability of submitting a disease report that is not directly associated with the presence of disease
    - for instance, farms with good management may be more likely to report disease problems than farms with poor management, but farms with poor management may be more likely to have disease than farms with good management:
        - a small number of reports from well managed farms, and no reports from poorly managed farms may indicate:
            1. that there is not much disease and
            2. that most of this disease is on well managed farms
        - however, in reality there is probably:
            1. quite a lot of disease and
            2. most of it is on poorly managed farms.
- associated with denominator data
    - the most common measures of the level of disease are *prevalence* and *incidence* (see the Glossary on page 153 for definitions)
    - both of these measures are based on:
        1. the count of the number of cases of disease
            - the numerator, or the number on top of a fraction, and
        2. the population (the total number of animals or farms, or the total at risk of getting the disease)
            - the denominator, or the number on the bottom of a fraction.

For example, if there were 300 sick animals in a population of 6000, the incidence would be 300/6000 or 5%, made up of the numerator (300) and the denominator (6000).

    - while surveillance systems are good at counting the number of cases of disease (numerators), it is often difficult to collect data on the rest of the population (the denominator).

- ongoing and regularly analysed
    - to detect and measure changes in the level of disease, it is necessary to take repeated measures
    - the surveillance systems should be able to produce regular estimates of the level of disease, and compare this to previous estimates.

Common problems with farmer reporting systems

While farmer reporting systems represent perhaps the most common form of surveillance, they involve large numbers of people and complex interactions between different groups (farmers, veterinarians, government officers, laboratories)

- there is, therefore a lot of variation in the way they operate.

Some common weaknesses with many farmer reporting systems are discussed here.

Reporting rate

This represents the major problem in all farmer reporting systems

- put simply, not all farmers will report disease problems.

The reporting rate is influenced by a large number of factors

- some are related to disease
    - very few farmers will report disease problems that they consider to be normal
    - slowly developing diseases are usually reported very late
- other factors are related to geography
    - laboratories tend to receive many more specimens from nearby areas than remote areas.

There are a large number of reasons for farmers failing to report. These reasons may need to be addressed in different ways, but some approaches to addressing one problem can also address a number of other problems. Examples of the reasons for not reporting include:

- Knowledge
    - The farmer may be unaware that they should report, or that the veterinary services are able to help with their disease problem
    - The farmer may not know that their animals are sick due to
        - Subclinical disease
        - Animals not under close supervision (such as animals grazing unattended in a forest for an extended period
- Apathy
    - The farmer may simply not care about reporting or the health of their animals
- Capability
    - The farmer may not be practically able to make a report due to
        - Absence of telecommunications (no telephone in the village)
        - Remote location from the nearest veterinarian and lack of availability of transport

        - Seasonal conditions making travel impossible
- Relationships
    - The farmer may have a poor relationship with the veterinary authorities or the local veterinary worker, making them unwilling to report.
    - This relationship may be poor because of failure of the veterinary services to resolve previous disease problems or provide any feedback after surveillance data was collected
- Fear
    - That diseased animals may be slaughtered
    - That no compensation will be paid
    - That the farm will be quarantined and sale of animals prohibited
    - General fear of dealing with the government
    - Of taxation, particularly of providing detailed information about livestock numbers and production
    - That reporting disease will cause adverse market responses
        - They need to sell their animals at a good price
        - Reporting disease may cause panic selling, and lower the market price

If the under-reporting rate were relatively constant (and could be estimated), then it would be possible to estimate the real level of disease:

- for instance, if it was known that only 20% of cases of a certain disease were routinely reported, and 400 cases were reported in a given year, then the estimated total cases of disease may be around 2000 cases
- however, the level of under-reporting is not constant in time, nor is it the same for different farmers and different locations
- reporting rates will rise and fall with public awareness factors
    - if there has recently been a well publicised outbreak of a disease (even if it is in another country), farmers are more likely to report any disease in their own animals
    - however, without regular media or extension reminders of the value of disease reports, the level of reporting steadily declines.

Relationships with veterinarians play an important role in the level of reporting:

- if there is no veterinarian nearby, then it is difficult to call the veterinarian and make a report
    - however, it is important to remember that this is a form of passive surveillance, where surveillance represents secondary use of the information
    - the primary reason the information is generated is because the farmer wants veterinary assistance with a disease problem
- if the farmer believes that they will have a better outcome by calling the veterinarian, they will call

- this decision depends on their assessment of the chances of the veterinarian helping the animal
    - if the animal is very sick or dies rapidly, there may be no point in calling the veterinarian (until the disease is seen to spread to other animals)
    - if the personal relationship between the veterinarian and the farmer is poor, they may be reluctant to call
    - if the cost of calling the veterinarian is high, they may not call
    - if there are possible severe negative impacts from calling the veterinarian (such as quarantine of the farm, fines, taxes or destruction of the herd for disease control with no compensation), then the farmer is very unlikely to call.

The value of the animals plays a large role in disease reporting:

- if a valuable stud bull gets sick, the farmer is more likely to call the vet, but if a chicken is sick, they may not
- changes in the value of animals can lead to a dramatic change in disease reporting
    - while prices for animals are high, reporting rates may be high
    - however if the values drop significantly, reporting rates may also drop as farmers are unwilling to spend money to treat sick animals.

Another reason for changes in reporting rates is a change in policy, staff or definitions

- for instance, if an unenthusiastic local veterinary officer is replaced with a very energetic officer, there may be a sudden increase in disease reports from that district – not due to a change in disease but due to a change in behaviour of the officer
- a change in policy introducing a requirement that every village must be visited once per month may result in an increase in disease reports
- a change in the definition of a case of disease from counting one an animal to counting one farm could result in an apparent sudden drop in the number of cases of disease.

All of these fluctuations in reporting rates mean that it is very difficult to interpret estimates of the level of disease based on farmer reports.

Field and laboratory reports

Many farmer reporting systems are based solely on data collected from diagnostic laboratories:

- this has the advantage that any disease diagnosis is supported by laboratory confirmation (rather than a presumptive clinical diagnosis from the field)
- however, many cases of disease do not require laboratory confirmation, or are not able to be confirmed at the laboratory, because (because samples cannot be

collected, or it is too far to the laboratory, or the sample is not good enough for analysis by the time it reaches the laboratory).

Field disease reports, based on history, epidemiology and clinical examination, provide valuable information, even if the diagnosis is less certain that that obtained from laboratory analysis.

Diagnosis

Within biological systems there is always a great degree of **variability**. This is the reason why there is always a risk that any diagnosis is wrong.

Two types of errors are possible:

1. declaring an animal as unaffected by a disease when it does have the disease (false negative), or
2. declaring it affected when it does not have the disease (false positive).

- if a false negative error is made, the disease is missed (with potentially important consequences if it is an emerging or exotic disease).
- if a false positive error is made, then a response may be made or treatment used when it isn't necessary.
- for surveillance, both types of error will mean that the count of the number of cases of disease is incorrect (unless they exactly balance each other out).

A diagnosis is normally based on balancing evidence from several sources. These include the history, clinical signs, epidemiological picture and any laboratory tests performed:

- a clinical diagnosis made in the field is often thought to be less reliable than a laboratory diagnosis. While it is true that it may be incorrect, it is usually supported by multiple sources of evidence (history and epidemiology).
- a laboratory diagnosis may often be more reliable, but if it is based solely on the result of a laboratory test, in the absence of other clinical information, there is still the risk of making an incorrect conclusion.

Standardised reporting

In some farmer reporting surveillance systems, field officers know that they are required to report certain diseases, but don't know exactly what they are meant to report.

- in these cases, a report consists of a letter describing the important aspects of the case of disease
    - however, one officer may feel that the clinical aspects are the most important, while another may focus on the epidemiological aspects, and yet another may focus on the economic or management and response aspects

    - while each report contains important information, it is not possible to undertake any comprehensive analysis, as each report contains completely different information
- in order to summarise and analyse surveillance data effectively, a consistent set of data must be collected from each case.

Speed of reporting

For early warning and response, the speed of reporting is critical. For the other objectives of surveillance, it is less critical, but nevertheless important.

The value of surveillance data rapidly decreases with age, and if the reporting system is so slow that each monthly report is only available one or two or six months later, then it is likely to be too late to respond to any problems detected in the analysis.

There are two common reasons for **delays** in reporting:

1. there is often a set reporting cycle, for instance, monthly
    - a summary of the disease cases for the month is created at the end of the month
    - this means that some information from the start of the month will always be a month old before it is reported.
2. delays in the administrative reporting pathway
    - a local officer may compile a report at the district level, and then send it to the provincial office
    - here, reports from each district are compiled, but this task can only be completed when the last district has submitted their report.
    - there may then be transcription, summarisation and analysis, before this report is then sent to the national level
    - similarly, national reports are only able to be analysed when all reports from all provinces are received
    - in some cases there are further levels of administration, introducing further delays.

Summarising data

A very common and significant problem of many passive reporting systems is that they deal only with summarised data:

- at each level of the administrative hierarchy, the number of cases of disease is summarised into a single figure for transmission to the next level.

For entirely paper-based systems, this approach makes the task of reporting much simpler:

- if there are 100 disease reports from one district, each on a separate sheet of paper, then at the provincial level, in a province with 10 districts, they would have to deal with 1000 sheets of paper
- instead, if each district produces a summary of the total number of cases of each disease, this can be sent as a single sheet of paper to the province. The province then simply has to add up the figures for the 10 districts to produce a provincial summary, before sending it to the national level. Finally, the national level just has to add up the data from each province for a national summary.

While this system makes the workload simpler, it makes meaningful epidemiological analysis of the data impossible.

Consider this **example**:

A country has a control program for foot-and-mouth disease (FMD).

- the program involves regular vaccination of animals at the village level
- surveillance has indicated that there are still a number of outbreaks occurring despite quite high rates of vaccination
- the veterinary services wish to determine if the vaccination is being effective or not.

By using summarised data available at the national level, it can be seen that there have been 20 outbreaks in one province, where 80% of villages have been vaccinated and 30 outbreaks in another province of similar size where 65% of villages have been vaccinated:

- it may therefore appear that the lower the vaccination coverage, the more outbreaks there are
- however, this data does not indicate where the outbreaks are occurring – in vaccinated or unvaccinated villages?
- as the only data received from the provinces is the total number of outbreaks per province, and the % of villages vaccinated, no further analysis is possible.

If, on the other hand, information for each outbreak included the village of the outbreak, and information on vaccination include the name of the village vaccinated, it would be possible to match this data for more detailed analysis.

- it may, for instance, be found that outbreaks occurred in both vaccinated and unvaccinated villages at about the same rate
    - this would indicate that vaccination was not providing protection against the disease
    - perhaps this problem is due to poor cold-chain for storage of the vaccination, or poor vaccination technique, or diversion of the vaccine so it is not actually being administered.

- if the simple analysis had been done, and it was concluded that the problem was due to vaccination coverage, then the veterinary services may have spent a great deal of money trying to increase the coverage
    - however, as the real problem was due to inadequate protection with vaccination this money would have been wasted, and the correct response would be to investigate why the vaccinated villages weren't protected.

Data analysis and interpretation

The above example of simple analysis illustrates why analysis is important:

- simply looking at the numbers is usually not enough to understand what is truly happening in the field
- in many cases, surveillance figures are used only to fill tables in annual report publications, and are rarely critically analysed to assess how well current strategies are working, or determine if new approaches to disease control are required.

How to improve a farmer reporting system

Reporting rate

The reporting rate is calculated as the proportion of true cases of disease in the population that are actually reported and recorded by the surveillance system.

The approach to improving reporting rates is:

1. Document the reporting process for a particular disease
    - note that reporting rates will vary for different diseases, depending on their clinical presentation, economic impact, level of farmer awareness,etc
    - it is therefore much easier to concentrate on one disease at a time
    - the analysis of the reporting pathway should show the steps required for a disease to be reported, such as:
        a. animal gets sick
        b. farmer notices animals
        c. farmer asks local officer for assistance
        d. local officer visits farmer
        e. local officer takes samples
        f. samples get to laboratory
        g. laboratory tests for the disease
        h. results reported from the laboratory to national office
        i. local office fills in field disease report
        j. field disease report sent to province
        k. province sends field disease report to national office

2. For each step, identify those factors that would increase the probability of the step occurring and those factors that would decrease the probability. For instance, *farmer asks local officer for assistance*:
    - factors increasing probability
        a. animal is valuable
        b. farmer trusts that veterinarian can help
        c. farmer knows that treatment will be cheap
        d. farmer is aware of dangers of disease spread to other animals
        e. farmer is aware of zoonotic potential
        f. farmer knows that any destroyed animal will be compensated
        g. farmer gets direct benefit by reporting
        h. farmer likes the veterinarian
        i. farmer is geographically close to the veterinarian
        j. veterinarian is easy to contact
    - factors decreasing probability
        a. fear of being blamed for the disease
        b. unable to contact vet
        c. animal of very little value
        d. unaware that vet can help
        e. fear that animal will be slaughtered without compensation
        f. farmer thinks that it is normal
        g. farmer think that they can manage the problem themselves or with local non-veterinary help
        h. fear of government or authority in general
3. for each of these factors, determine whether the veterinary services can influence them. For example:
    - animal is valuable: unable to influence
    - farmer is geographically close to the veterinarian: able to influence
4. for those factors that can be influenced, determine how they can be influenced:
    - farmer is geographically close to the veterinarian: influence by putting new veterinarians in remote areas
5. for those factors, estimate the cost that this would require, and the improvement in reporting that it would achieve. For example:
    - putting new veterinarians in remote areas
        - cost:
            - setting up veterinary office
            - salary of veterinarian
            - transportation costs
        - benefit:
            - increased reporting from that veterinarian's local area from current reporting rates (very low) to the same sort of rate as other areas (moderate)

determine the available budget for improving reporting

list possible interventions in order of size of benefit (expected increase in reporting rate)

identify the one (or combination of several) interventions that fit within the available budget, and achieve the maximum increase in reporting rate

common interventions include:

- public awareness campaigns, using general media (television, radio), or targeted (posters at livestock markets, information at feed suppliers)
- professional training for field staff to increase reporting rates
- provision of incentives for reporting (cash or other benefits to farmers and/or vets that identify cases of priority diseases)
- provision of adequate compensation for slaughtered animals

Improving relationships

Improving relationships between farmers and the local staff (such as the district veterinarian or the village veterinary worker) is an important step in improving reporting. Some of the problems in relationships are to do with personality and are very difficult to overcome, but others may be easier to address. For instance, developing the skills of local staff so they are in a better position to help with routine practical problems will make them more valuable to the farmers. Similarly, it is important to ensure that there is useful feedback from every disease event, including advice on how to prevent or treat the problem in the future.

Addressing fear

There are many reasons why farmers may fear reporting, and some of these (from the farmers point of view) are justifiable. It is important to try to understand each of these reasons and address them as well as possible.

Some can be addressed through providing information and assurances. For instance, it may be good to guarantee that the information collected for surveillance purposes will not be used for taxation purposes.

Lack of compensation or compensation levels that are too low, pose a major problem for disease reporting. It is often not possible for those involved in disease surveillance to have a significant influence on compensation policy. However, decision makers often believe that compensation cannot be used as it is too expensive. Some simple epidemiological and economic modelling may provide new information to either support or refute this position. Consider the following example:

Two different scenarios are compared, one with compensation and one without. Where there is no compensation, the reporting rate will be low. This means that disease will be harder to control, the costs of control will be higher, and the impact on production will be higher. These costs can be estimated. In the scenario where compensation is used, there will be higher reporting rates and earlier reporting, decreasing control costs and allowing the outbreak to be eradicated more quickly. By considering all of the costs of

disease control and the impact on production, it may become clear that paying compensation is actually saving money, rather than costing money. This type of analysis may be useful to help decision makers when developing disease control policy.

Improving knowledge

Improving public awareness of priority diseases and the importance of rapid reporting is a key way to improve the farmer reporting system.

- Television, radio, newspapers and posters have all been used to raise awareness about reporting diseases such as FMD in pigs and HPAI in poultry.
    - such announcements help increase the level of awareness of farmers that any abnormal sign they see in their animals are reported as FMD or HPAI suspects

    - This approach increases reporting for the targeted diseases, but may have no impact on reporting of other diseases.
    - "Accidental" public awareness can often result from high media coverage of animal disease problems in other parts of the world. For instance, during well publicised disease outbreaks in Europe, reporting rates in the rest of the world are likely to increase.

Overcoming problems with capability for rapid reporting

There is much investment in farmer trainings (e.g. farmer schools, focus group discussions, etc) with an emphasis on disease reporting. The advent of technology has helped:

- Cambodia has a telephone hotline for farmers to report suspect cases
    - this information reaches the central veterinary services by which after receiving it, coordinates with the local veterinary authorities to verify the information
    - this hotline is announced through the radios and included in posters distributed to different provinces
- Vietnam is trying to use the SMS technology where farmers who can afford to have mobile phones send an SMS message to the Department of Animal Health
- Indonesia also uses SMS reporting, and heavily invests in training farmers to enhance reporting of surveillance data.

The initial set-up and training costs for the implementation of technology-based reporting systems (such as SMS systems) are often perceived as being high. However, if the system is well implemented, the value of the boost in completeness and speed of reporting is likely to far outweigh any establishment costs.

More accurate diagnosis

Minimising false negatives, in particular, but also false positives will improve the quality of the surveillance system.

As the staff of the veterinary services are the ones responsible for making the diagnosis, this can be achieved by improving the skills of those staff:

- for field staff, options include:
- providing further training in the diagnosis of key diseases:
    - this should include field exercises to examine affected an non-affected animals
- providing diagnostic manuals for the key diseases:
    - manuals should provide the key diagnostic information in a format that is easy to use by veterinarians or animal health staff in the field
    - clear pictures, diagnostic criteria, and instructions on collection and transportation of appropriate diagnostic samples should be included
- provision of expert assistance:
    - a provincial or national expert should be available to assist field staff with investigations and diagnosis
    - where practical, this may involve field visits, but could also be done via mobile telephone with the local veterinary officer was investigating the case.
- field diagnostic kits can help support field staff with rapid results for certain diseases.
- laboratory diagnostic capabilities can be assisted by:
    - advanced staff training
    - ensuring quality control systems are working well
    - introducing better diagnostic tests
    - ensuring reagents are of high quality.

Data management

Traditionally, most reporting systems have been paper-based. The widespread availability of computers in provincial and regional animal health offices in most countries, and the increasing availability of the internet for communication between offices mean that **computerised data management** is now possible in almost every situation.

Computerised management of data has several key advantages over paper-based systems:

- rapid reporting:
    - information gathered in the field can be instantly and simultaneously available at district, provincial, regional and national offices
- ability to handle large volumes of data:

    - there is no longer a need to aggregate data at multiple levels of the reporting hierarchy
    - previously this was done because it was not possible to manage large amounts of paper
- automated analysis:
    - routine analysis can be automated so that it is instantly available and frees up staff time for more important tasks (like interpreting and responding to the data)
- data sharing:
    - copies of the data or analysis can be provided to the different groups that need it.

Standardisation of reporting

Surveillance data are only useful for analysis if the data items collected are consistent and standardised. Data is normally first collected in the field using paper.

To encourage standardisation:

1. develop a single standardised paper form for data collection
    - this form should be developed to collect all data to meet the needs of the surveillance system
    - some suggestions for designing a good form include:
        a. keep it as short as possible:
            - only include those items that are absolutely necessary
            - the longer a form and the more effort and time that is required to complete it, the higher the chance that it won't be completed at all, and the lower the quality of the data that is completed
        b. make it quick to complete:
            - where possible, use tick-boxes to indicate responses, rather than writing out words in full
        c. ensure that the flow of the form is logical:
            - if there are some parts that should only be completed in certain circumstances, make this clear
        d. ensure that there is a field for comments, so that any unusual aspects can be explained
        e. don't limit possible diagnoses:
            - common diagnoses may be listed, but ensure that field staff can report other less common diagnoses
        f. avoid duplication:
            - make sure that the staff don't have to write the same thing in different places or on different forms.
2. train staff in the use of the form:

    - provide a short, easy to read guide on how to complete the form, with plenty of examples
    - run training courses which involve field diagnostic visits so staff can practice filling out the form to describe cases, and can ask questions while they do it.

Normally, the first data to be recorded will be on a **paper form**. However, it may sometimes be possible for veterinary staff to record data in a farmer disease reporting system **directly into a computer**. This approach makes it much easier to collect disaggregated data rapidly (see below), but also can ensure that high quality data is collected.

Examples of situations where computer recording of field surveillance data may be possible include:

- laptop computer
    - it may sometimes be possible for staff to carry a laptop computer to the field with them, but this is unlikely to be common
    - records in the computer can be uploaded to a central system on return to the office
- hand-held devices
    - this is more feasible, as hand held computers become cheaper and more common, particular combined with mobile phones
    - a simple data recording form could be programmed into the hand held device/mobile phone, and data uploaded either immediately (through the phone) or later, by synchronising with a computer at the office
- mobile phone text (SMS) messages can be used for simple targeted disease reporting
    - a short message using a standard format or coding can be sent to a central computer for immediate submission of data
- a telephone can be used to record data into a computer
    - the field veterinary staff could telephone to the office, where data entry staff could record the information directly into the computer.

Recording information **directly into a computer** has a number of advantages:

- in terms of standardisation, the computer can have a number of data quality checks programmed in, and require certain data to be submitted:
    - for example:
        - a disease report could not be submitted until the number of affected animals has been entered
        - the computer can ensure that the number of animals that have died from disease cannot be greater than the number of animals that have been affected by the disease
    - these quality control checks are not possible on paper forms

- while paper forms may be entered into a computer later, if errors are found, it is often to late to correct them
- this is why immediate computerised data entry in the field provides better quality data.

Rapid reporting

Many farmer disease reporting systems fail to rapidly provide data for analysis and decision making.

Making data reporting **faster** involves an analysis of the existing system to determine where the main delays are, and to determine how these may be overcome:

1. identify all the steps in the reporting system between the animal becoming sick and a report of the analysed data being available to a decision maker
2. for each step, determine how long it takes
    - you may record the typical time as well as the longest time
3. focus on those areas that introduce the most significant delays, and determine how they can be made more rapid.

One effective approach is to **shorten** the reporting pathway, so that field reports are transmitted from the field to the central office more directly

- this is simpler if reports are able to be entered into a computer as early in the reporting pathway as possible.

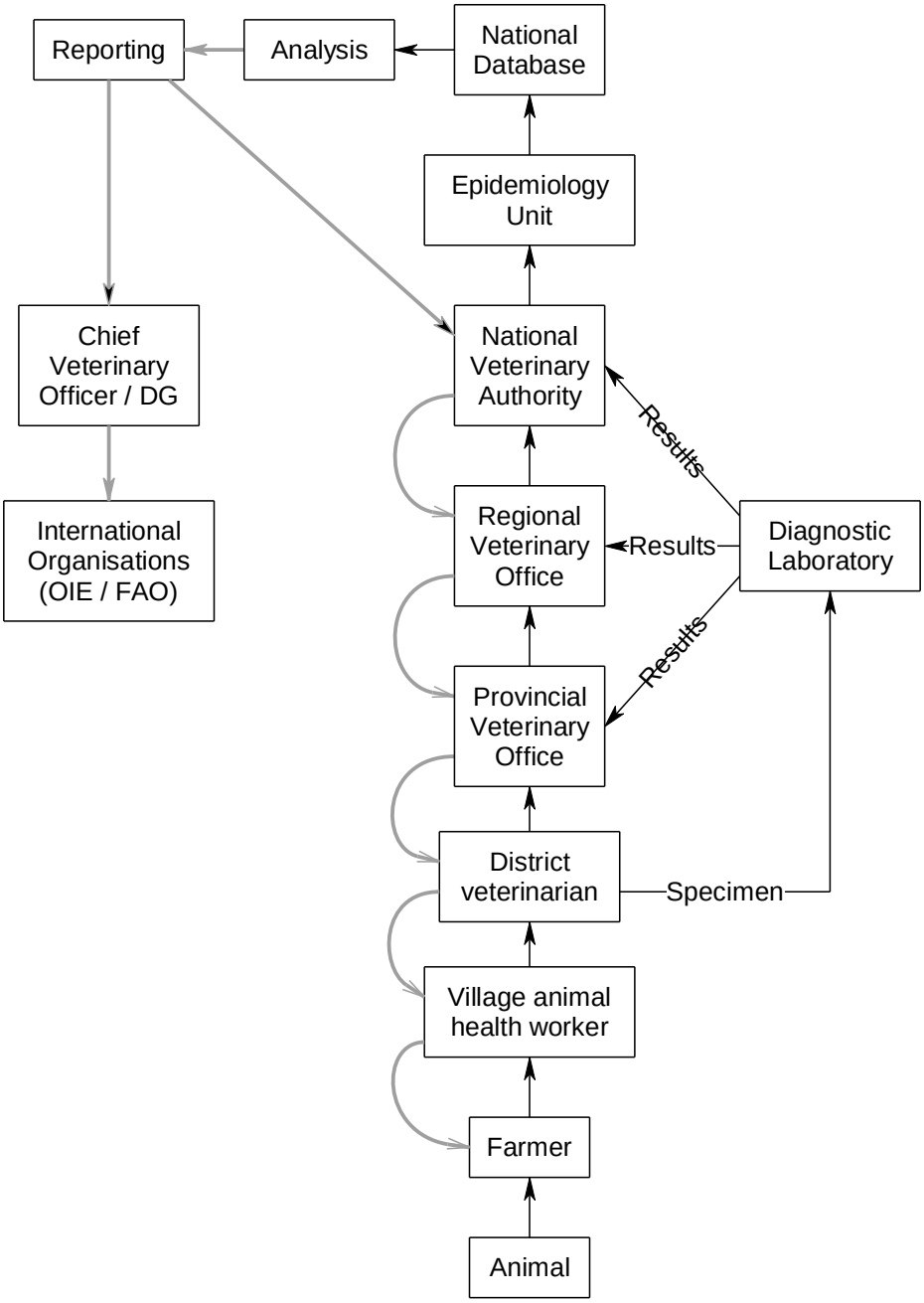


Figure 6: Example of a traditional reporting system

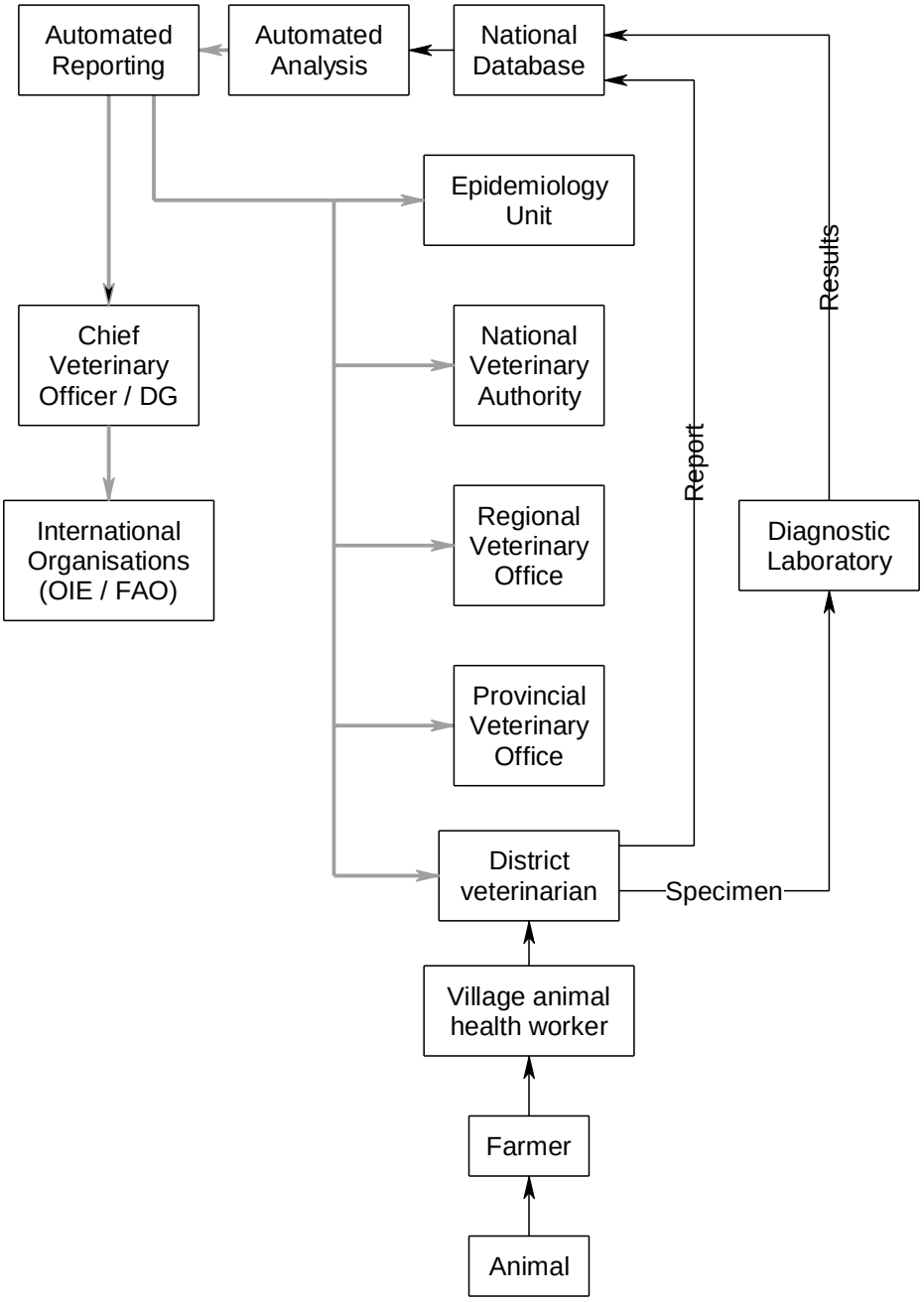


Figure 7: Example of an alternative reporting system. Direct reporting to a central database shortens the reporting pathway. Centralised access to reports generated by the database means that all levels can get access to the data required immediately.

The **principles** of using computerised systems to make disease reporting as rapid as possible are:

1. enter reports into a computer as early as possible
2. do not transcribe, analyse or summarise data before entering it into the computer:
    - data should be entered from the original forms
3. where possible, data should be stored in a single centralised database, accessible over a network (either the internet or a wide area network (WAN))

    - if this is not possible, data should be stored in local databases at the office where the data is entered
    - databases for each office should be identical or at least compatible, and data from each office should be merged in a central database as quickly as possible (for instance by sending email files or disks through the mail to the central office)
4. other data users in the reporting hierarchy should have instant access to the centralised data
    - for instance, if data is entered into computers at the district level and stored directly in a database at the central office, the provincial offices should have immediate access to the data as soon as it is entered.

Disaggregated data

As described above, **disaggregated** data is necessary for meaningful epidemiological analysis:

- the use of computer-based systems makes it easier to manage large volumes of disaggregated data
- another key aspect is decentralised data entry
    - mailing completed forms to the national office for data entry there would provide access to disaggregated data, and make it reasonably rapidly available, but the volume of reports that need to be entered would be overwhelming
    - sharing this task around the field staff means that the workload for each individual is much lower, and also has the advantage that the data is being entered by the person that collected it
    - if any errors are detected, they can be immediately corrected.

Integration of different data types

Effective analysis often requires access to a number of different types of data:

- for instance, when planning a response to a disease outbreak, it may be decided that ring vaccination is necessary
- planning this vaccination requires knowledge of:
    - where the outbreak is
        - from the farmer disease report
    - the population of susceptible animals in the neighbouring area
        - from disease population reports
    - an indication of the last time these animals were vaccinated
        - from vaccination reports
    - only with these three data types can sensible decisions be made about which animals to vaccinate, how much vaccine will be needed, and how much money and how many staff will be required.

Computerised data management with a database that allows access to data of different types allows this sort of efficient use of data:

- if vaccination, disease and population data are all managed by different offices, stored in different types of formats (some in databases, some in spreadsheets and some in tables in word processing documents), this type of data integration is **not possible**.

Automated analysis

The purpose of the surveillance system defines the common types of outputs that are required:

- if one of the aims is to support demonstration of freedom from disease, the data should be routinely analysed to report if any cases of that disease have been seen, and the probability of disease freedom if it has not
- if the aim is to describe the distribution of disease, measures of disease prevalence at the provincial or district level should be generated each month and mapped
- These tasks can be *'automated* so that the staff responsible for disease management and control are quickly provided with the information they need (rather than spending hours on repetitive tasks).

Abattoir surveillance system

Abattoir surveillance is commonly used as a form of **passive** surveillance.

Its primary advantages are that it:

- is inexpensive
    - animals are being processed and inspected for other purposes, so the costs are primarily only related to data capture and any laboratory tests performed
- is able to cover a very large number of animals
- allows collection of diagnostic specimens, such as blood or tissue samples, for laboratory testing
- provides a relatively constant supply of surveillance data
- enables data to be collected from a relatively small number of abattoirs locations, which slaughter animals from a large number of farms or villages (thereby decreasing the data collection costs).

Active, targeted surveillance can also be carried out at abattoirs, to take advantage of some of these benefits.

Description

Abattoirs vary significantly from country to country and area to area:

- highly industrialised commercial abattoirs are sophisticated factories with large work forces and tightly controlled food hygiene and safety requirements
- in contrast, there may be village abattoirs that operate outdoors and slaughter only a very small number of animals under poor hygiene conditions.

The **types of surveillance information** that can be collected from an abattoir include:

- routine meat inspection findings:
    - in all but the smallest abattoirs, there is some form of meat inspection
    - the purpose of meat inspection is to ensure that the meat is fit for human consumption
    - normally, a limited number of parts of the carcass and viscera are examined, with the aim of detecting or excluding a limited number of specified conditions:
        - for instance, specific lymph nodes may be examined to detect granulomas, in order to be sure that the animal is not affected with tuberculosis
    - if the findings of routine meat inspection are recorded and captured by the surveillance system, these may provide a useful source of surveillance data:

        - it will not provide any information about diseases which cannot be detected during routine inspection, but will provide information about those that can be
    - in many abattoirs animals are examined before slaughter, as well:
        - these examinations are rarely detailed, but aim to detect obvious injuries or lesions, or to detect signs that may indicate that an animal is clinically ill (such as signs of depression or fever)
        - this information may be used to supplement the meat inspection findings.
- targeted specimens for laboratory analysis:
    - abattoirs offer a valuable opportunity to collect specimens that cannot be easily collected from live animals
    - the simplest is the collection of blood, but it may include tissue specimens as well
    - large numbers of samples can be collected very rapidly at a busy abattoir, making this task simpler and cheaper than collecting similar specimens in the field
    - the ability to collect specimens depends somewhat on the nature of the abattoir and the type of specimen required:
        - **blood** is best collected as soon as the animal is killed and while it is being bled:
            - in a busy commercial abattoir, this is one of the most dangerous and therefore strictly controlled areas of the plant
            - this is because it is the only place inside the abattoir where there are live animals, and there is a significant risk of injury to workers as they are being killed
            - therefore, even if there is plenty of blood available to be collected, it is necessary to consider carefully how it can be collected without danger or disrupting normal abattoir operations
            - collecting blood at smaller, less busy abattoirs may be easier
        - **tissues** can often be collected as or after the viscera are removed from the carcass
            - the ability to take tissue samples depends on the way in which tissues are used
            - if whole livers are used for sale, the abattoir may be reluctant to allow samples to taken, and may require them to be purchased
- enhanced inspection:
    - routine inspection may detect only a limited number of conditions

- if a study is being conducted into a specific disease that can be detected at post-mortem examination, it may be possible to do special inspections to detect this disease at the abattoir
    - this may be done by external research or surveillance staff, or existing meat inspectors could be trained to do more detailed examinations to detect the disease
    - these more detailed examinations may be further improved by the collection of specimens by the meat inspectors for laboratory confirmation.

Objectives

Abattoir surveillance may support a number of objectives, including:

- early warning of incursions of emerging or exotic diseases
- description of the level or distribution of existing diseases
- demonstration of freedom from disease
- monitoring progress with control programs.

The requirements to meet these objectives are similar to those described for farmer reporting systems.

Common problems

There are a number of common problems with abattoir surveillance that may make it difficult to achieve the surveillance objectives.

Non-representative population

The biggest problem with abattoir surveillance is that animals that are sent to the abattoir are normally well-grown, **healthy** animals that will get a good price:

- the abattoir population either excludes or significantly under-represents very young stock, sick or poorly grown animals, and animals that are not produced primarily for meat (breeders, milking animals, draught animals)
- this means that any conclusions made on the basis of abattoir surveillance are valid only for the population of animals slaughtered, and cannot be extended to the general population:
    - normally, abattoir surveillance underestimates the prevalence of disease, as diseased animals are less likely to be found at the abattoir.

The value of abattoir surveillance when demonstrating freedom from disease depends on the disease of interest:

- if it is a disease that can be detected reasonably well at meat inspection **and** has a significant subclinical phase, the chance of detecting it at the abattoir may be quite high:
    - tuberculosis is an example of this type of disease
    - examining lymph nodes for granulomas and then culturing every positive node detected to exclude tuberculosis from the diagnosis can provide reasonably strong evidence that tuberculosis is not present in the population.
- abattoir surveillance provides little support for claims of freedom from diseases that are either difficult to detect on meat inspection, or that cause rapid death or otherwise mean that affected animals are very unlikely to be sent to slaughter.

Diagnosis

The level of diagnosis depends on the nature of the data collected:

- if only meat inspection or pre-slaughter inspection data is used, the data normally lists only observed abnormalities, rather than makes any diagnosis as to the disease that caused the abnormalities
    - for instance, petechial haemorrhages on the intestines may be observed and recorded, but could be caused by a number of different diseases
    - in this way, meat inspection findings can be thought of as a form of syndromic surveillance, which is discussed later
    - analysis of the data depends on detecting changes in the patterns of signs, rather than in the pattern of diagnosed disease
- when more detailed examinations are performed, or when specimens are sent to the laboratory, it may often be possible to make a definitive diagnosis
- in some cases, a diagnosis is not required, as the purpose of the surveillance is just to measure the immune status of the animals.
    - for instance, blood may be collected to test for antibodies to a specific disease.

Lack of associated data

There are a number of possible objectives for surveillance, listed above:

- for example, the data may be used to estimate the *prevalence* of disease
- this requires:
    - a count of the number of affected animals
    - the size of the population:
- in abattoir surveillance, the number of affected animals is easily counted, and the size of the population is the total number of animals examined.

However, analysis of surveillance data may often be more complex, and require some **supplementary data**

- for instance, there might be interest in the *distribution* of disease
- supplemental information required:
    - where each animal comes from (village, district or province).

Surveillance data may also be used to *test hypotheses* or *examine potential risk factors*:

- for instance, is this disease more common amongst young animals or older animals, are females affected more than males, are antibodies due to vaccination or disease?
- to answer these questions, we require data not only on the disease status of the animal, but also some other descriptive information (its age and sex).

When data is collected in the field, at the farm of origin of the animal, and in the presence of the owner (as is normally the case with farmer reporting systems), it is possible to collect all this information

- however, with abattoir surveillance it is commonly not available
    - all that is available is the tube of blood, or the viscera that are being examined or sampled
- the absence of any data on the animal **limits** the value of abattoir surveillance data.

Lack of access to surveillance data

While many abattoirs routinely undertake pre-slaughter inspection and meat inspection, the purpose is to identify if any animals are unfit for human consumption and should therefore be condemned:

- once the decision to condemn has been made, and the meat marked appropriately, the abattoir has no further use for the information
- for surveillance, however, the information may still be very useful, but in many cases it is not recorded:
    - if it is recorded, it is often only recorded on a piece of paper (which is later placed in a filing cabinet), or on a chalk board (which may be summarised, and then cleaned off).
    - either way, meat inspection observations are often not available for use for surveillance purposes.

Lack of general information data- origin of the animal

There are different classifications of abattoirs. There are:

- small abattoirs that service municipalities where information on origin of the animals could be gathered
- provincial abattoirs that cater to all traders that bring their animals for slaughter because such abattoir is the nearest point to their market

- big abattoris that service a metropolitan city but more often the animal origin could only be traced to the last province where the animals were last sourced
    - the market vendor or trader brings the animal to the abattoir for slaughter
        - these traders usually bought the animals from livestock markets or holding yards
    - this means that animals have passed through a lot of owners before reaching the end stage
        - with no identification system,or a rapid changing of paper ownership, it would be difficult to keep track of the origin of animals for slaughter
    - records kept are mostly the species and number of that species brought in for slaughter to determine the fees to be paid
    - a conscious effort to ask the trader or the vendor where the animal came from would have to be made if this kind of information is needed, as well as a conscious effort also on the part of the abattoir manager or meat inspector.

How to improve abattoir surveillance

Improving diagnoses

The ability of meat inspectors to detect different diseases varies widely:

- the main factors affecting these abilities are:
    - training
    - experience
    - time taken on each carcass
- providing extra training to meat inspectors to help them identify priority diseases will increase the sensitivity of the system
    - use of specialist inspectors with better training and more experience is an alternative.
- in a commercial plant, it is generally not possible to slow down the processing line so that inspectors can have more time
    - an alternative to allow better examination is to sample from the line by taking every second or every third animal, rather then doing a detailed examination of every animal.

Accessing associated data

There are two approaches to improving the collection of data describing the animal:

1. maximise the data that can be collected from the carcass
2. link to or gather more data from the producer.

Carcass data

At the abattoir, the core data collected may be observations based on meat inspection and blood or tissue samples.

Additional information about the animal can be obtained by observation of the rest of the carcass:

- by observation it is possible to tell its sex, and its breed
- animals may be weighed, and this can indicate its condition
- inspection of the teeth can help estimate its age.

All of these details can be recorded, but some may need to be noted at different points along the processing line:

- for instance, it may be easier to record breed and sex before the animal is skinned
- weighing may happen automatically further down the chain
- inspection of the teeth may be most easily done when the head is removed.

If data is collected at different points along the processing line, it needs to be linked to the inspection observations or the sample:

- simple systems can be used to make this process as easy as possible
    - for instance, recording sex and breed on a tag that accompanies the animal along the chain until the viscera are inspected
    - all details can be recorded together at that stage.

Data from the producer

The other way to collect data about animals is to gather it before the animal is slaughtered.

If the key data is collected and recorded and then the animals are uniquely identified prior to slaughter and during processing, the extra information will be available for analysis.

For example:

- in a lot of 20 animals, each animal may already be identified with a unique ear tag
    - if not, a temporary tag (such as a tape tail tag) can be applied
- a form is completed providing the necessary information against the identification of each animal, such as:
    - sex
    - age

    - place of origin
    - vaccination status
- as the animal is slaughtered, the identifying tag is kept with the carcass until the specimens are collected, or the meat inspection is completed
- specimens or inspection data are then recorded along with the identification number of the animal
- this is then submitted along with the original form with data for all the animals, so the numbers can later be linked for analysis.

Data can be collected at several different levels:

1. data collection from the person delivering the animal to the abattoir
    - the person delivering the animals may be the owner, but could be just a middle-man or trader, and therefore may not know things like the vaccination history, or even the place of origin of the animal.
2. data collection from the producer
    - producers may be required to complete a form for all animals that are sent for slaughter
        - this form could be passed to any transport or trader to be kept with the animal
    - this approach collects better quality data, but is more difficult to implement
    - examples of such a system exist in several countries, such as the Australian livestock vendor declaration.
3. whole of life record-keeping
    - the most comprehensive system of recording data about animals is to use a whole-of-life recording system
    - this may take the form of a paper 'passport' style document, or electronic centralised data recording and use of RFID (radio frequency identification) electronic tags
    - either way, all key events in the life of the animal can be recorded, and are always linked to that animals' ID number
        - linking existing data to abattoir samples or observations is much easier when the animal is already uniquely identified
            - many countries already have, or are introducing programs for the individual identification of animals of key species
            - this assists with food safety issues, as well as helping with trace-forward and trace-back during disease control activities
    - when the animal arrives at the abattoir, the 'passport' is inspected, or the central database can be queried.
    - systems like this are being used in some countries or regions where there are significant concerns about food safety issues

- for instance, the EU has adopted a paper passport system as part of its control measures targeting bovine spongiform encephalopathy (BSE), and Australia has introduce the National Livestock Identification Scheme based on electronic ear or rumen tags and central data recording.

Data management

If the process of collecting and recording data is too slow and too difficult, it will result in delays, inaccurate data or complete failure to record the required data:

- systems should therefore be developed to make the process of data recording, transmission and analysis as simple as possible.

At its most basic, simply counts of the number of cases of different diseases kept on a sheet of paper or blackboard are simple to implement

- these can be transcribed and sent to a central office for entering into a computer
- however, retyping data is prone to error, and if there are questions, it may not be easy to contact the person who generated the data.

In all cases, it is better, where possible, to try to develop systems that allow the data to be entered into a computer as early in the data collection process as possible

- if a computer is available at the abattoir or the office of the meat inspector, the person doing the meat inspection can enter the data
    - this minimises problems with recording the data.
- electronic data capture at the time of inspection removes the need for re-typing, making it faster and more reliable
    - some abattoirs use a touch-screen keyboard, with simple buttons for each of the key findings
- options for voice-controlled data recording have been explore
    - the meat inspector wears a headset connected to a computer (e.g. by wireless connection)
    - simply saying the name of an abnormal finding prompts the computer to record that finding
- in many cases, where resources are limited, none of these options will be possible.

Whatever the system used, be it chalk and blackboard, or voice-controlled data recording, if the data is to be useful for surveillance and early detection purposes, it should be made available for analysis as quickly as possible.

Electronic transmission of the data to a central database should be used, along with automated analysis as previously discussed.

Veterinary negative reporting system

A veterinary negative reporting system is a specialised surveillance system designed to provide evidence of freedom from disease.

Description

This system is a type of **passive** surveillance, which aims to document information that is being generated for other purposes.

Veterinary staff routinely visit farms, villages and other places where animals are kept for a range of reasons:

- examining and providing treatment to clinical cases
- vaccination and other control activities
- inspections and certifications and so on.

During the course of these visits, there is normally an opportunity to chat with the livestock owners, and to see the other animals.

If the veterinary services are aiming to demonstrate that a country or zone is free from a disease that normally shows clear and obvious clinical signs, each visit by veterinary staff provides evidence:

- this is because, even if specific examination of animals is not undertaken, it is very unlikely that a disease like foot-and-mouth disease showing its normal manifestations in cattle or pigs for instance), could be present in a farm or village during a veterinary visit, without the farmer asking the veterinarian about it, or the veterinarian noticing the disease in the animals.
- the fact that disease was not noticed at a routine visit can therefore be seen as evidence that the disease was not there:
    - the 'test' in this case is talking to the owner, and inspecting the animals from a distance
    - clearly, this test is not perfectly sensitive, and has low sensitivity in early cases of disease, but it is certainly very inexpensive.

The surveillance system is based on documenting and collecting the information from routine farm visits:

- after each visit, the veterinarian completes a brief report which includes the location, the date and confirmation that the target disease was not seen or reported during the visit.

Information from the veterinary negative reporting system can be used in response Carl Sagan's often quoted phrase: ‘absence of evidence is not evidence of absence’:

- to provide evidence that the disease is absent, a simple absence of reports is not adequate
    - this surveillance system generates documented evidence that the disease is not present.

Over time, the number and coverage of these reports can provide significant evidence that the country or zone is free from the disease in question.

Objectives

This system is used only when aiming to demonstrate freedom from disease.

Common problems

One significant limitation of the system is the **sensitivity** of the test for disease detection:

- for diseases that show clear, important and easily noticed clinical signs, the sensitivity is high:
    - this is because the farmer is likely to have noticed the disease, and if not, the veterinarian could identify diseased animals from a distance
    - high levels of farmer awareness of the disease will also increase sensitivity
- however, this approach has little value when the sensitivity is very low:
    - with diseases that are difficult or impossible to detect from a distance
    - when farmer awareness is low.

As this becomes a routine activity of the veterinarian or technician assigned in a particular village, there is a tendency to become lax about asking farmers and examining their animals, so that the veterinarian or technician routinely signs a negative reporting form and submits it through the reporting channel.

How to improve

The key factors to making this system as useful as possible are:

- apply it only to the right diseases
- ensure that farmer awareness is high, so reporting levels would be high if the disease were present
- use a short, simple and quick to complete reporting form, so that veterinary staff do not have a significant extra task
- ensure efficient processing of the report forms, and data entry into a centralised database
- provide regular feedback to veterinary staff to ensure that their level of awareness and level of enthusiasm remains high

- ensure that there are audit systems in place to ensure that the field veterinarian or technician exerts a conscious effort to really talk to the farmers and examine the animals
    - audit systems may consist of a verification system to check the areas listed in the report if such visit was made on that day.

Sentinel herds or flocks

A sentinel is one who stands guard to warn when something happens.

Sentinel herds act as indicators for the rest of the population to warn that disease is present.

Description

A sentinel herd usually consists of a relatively small number of animals, kept together, that are visited on a regular basis and tested:

- testing usually involves blood testing to check for antibodies to specific diseases
- testing may also involve clinical examination or tests for a specific disease agent.

The typical operation of a sentinel surveillance system is as follows:

- a relatively small number of sentinel herds are established in areas considered at high risk of disease incursion
- where possible, animals are individually identified
- when animals are first introduced into the sentinel group, they are tested to ensure that they are susceptible to the target disease (i.e., they do not already have antibodies)
- at each subsequent test, the antibody status is assessed
- if an animal is antibody positive, then it indicates that that animal has been exposed to the disease in the time between the current test and the previous (negative) test.

Sentinel herds or flocks are therefore distinguished from other systems by being a relatively small group, being identified, placed in a fixed strategic location and monitored over time.

Objectives

Sentinel herds and animals can:

- be used for early warning of the incursion of a disease into a previously free area
- provide evidence of freedom from disease
- help describe the distribution of disease
- help assess the effectiveness of disease control measures

The frequency of testing depends on the objectives of the surveillance and the local situation. For instance, if the objective to to provide evidence of freedom from infection and the disease is seasonal, one single test per year at the end of the season may be adequate. However, if the purpose is early warning, monthly or weekly tests may be required to ensure that the infection is identified as quickly as possible.

Sentinel animals may be used to assess the effectiveness of control measures. For instance, if a farm has suffered an outbreak of disease, and all the animals have been removed while the farm is disinfected, it is important to know if the disinfection has been successful before any animals are reintroduced. If a small number of sentinel animals in the farm and they are examined regularly with no evidence of disease, it provides assurance that the disinfection has been successful.

The same approach can be used after vaccination. Vaccination can often mask the appearance of signs of disease, while failing to completely stop the circulation of the disease agent. A small number of unvaccinated sentinel animals may be placed with a vaccinated population, and tested regularly to ensure that there is no pathogen present.

Common problems

Establishing and maintaining a sentinel herd can be expensive:

- the animals need to be identified and confined
- they need to be made available for testing at regular intervals (e.g. monthly)
- as a result, the number of herds and the number of animals per herd is relatively small, resulting in **low population coverage**.

Sentinel herds are therefore not particularly useful as early warning systems for diseases that are primarily spread through animal movement of fomites, for example

- such diseases can spread great distances rapidly through the movement of live animals
    - the location of new outbreaks is very hard to predict
- with a small number of sentinel herds, the chances of one of those herds being infected during the early stages of an outbreak of a disease like classical swine fever, for instance, are very small.

Sentinel surveillance is most valuable when used for diseases which spread as a solid front or wave, such as vector-borne diseases:

- an incursion of a vector-borne disease from an infected to an uninfected area usually occurs through spread of a vector
    - however, it may occasionally occur due to live animal movement
- this usually occurs due to environmental factors such as weather changes
- vectors are assumed (probably a little too simplistically) to move as a mass, like a pool of liquid spreading on a flat floor from a leaking container
- even if there are only a small number of sentinel herds, if they are located in areas considered to be at greatest risk, the wave of infected vectors will come into contact with the sentinel animals as it passes
- sentinel animals generally attract vectors, increasing the risk of detection.

How to improve

- consider the way the target disease is spread, and if sentinel surveillance is the best approach (limit to vector-borne diseases in most cases)
- pre-bleed animals to ensure that they are antibody negative
- bleed animals regularly
- have a replacement strategy so that sero-negative animals can be brought into the herd to replace any animals that have seroconverted.

Surveys – representative and targeted

Surveys are often seen as the best way to do surveillance, but they can be costly and logistically challenging.

They are a form of active surveillance, so the veterinary services have full control over the design of the survey and the data collected.

Description

Surveys can be one-off or repeated activities.

The key advantage of surveys:

- the sampling strategy can be developed to exactly meet the needs of the veterinary services and decision makers
- with many other forms of surveillance, there is always a compromise between the data needed to support decision making and the data available.

There are two main approaches in survey sampling:

1. take a representative sample:
    - this is the most common form of survey
    - with this approach, it possible to confidently calculate measures of the level or disease, or probabilities of disease freedom, without the fear of error due to bias.
    - *Survey Toolbox*, Parts I and II (Chapters 2 to 9) deals with most aspects of livestock disease surveys, and chapter 3 (page 37) concentrates on techniques to ensure a representative sample.
2. use targeted sampling
    - this approach is used to:
        - detect disease or
        - demonstrating freedom from disease
    - animals are chosen from high risk groups, so that if the disease is present, there is a better chance of detecting it than if purely representative sampling was used.

Objectives

Surveys using **representative** sampling:

- are the best way to get unbiased data allowing reliable estimates of the level and distribution of disease
- can also be used to demonstrate freedom from disease.

Surveys using **targeted** sampling:

- are an efficient way to detect disease
- provide evidence of freedom from disease
    - however, advanced modelling techniques are required to validly analyse the data.

Common problems

The main problems of surveys compared to other approaches to surveillance are the costs, and the logistical challenges

- however the increased costs may often be warranted, given that the data derived from a survey is often more reliable than data from other sources.

How to improve

Conducting an effective survey is complex, and there are many aspects that must be carefully considered:

- *Survey Toolbox* discusses many of these in detail and should be consulted when planning a livestock disease survey.

Syndromic surveillance systems

Various forms of syndromic surveillance have been used for many years.

However recent interest from the field of human surveillance has lead to a great deal of interest and research in the area.

Description

A syndrome is defined as a collection of signs that indicate the presence of a disease.

- syndromic surveillance is therefore concerned not with the detection and reporting of disease, but of the signs and groups of signs that are associated with disease
- these signs may be clinical signs (such as fever, lameness, diarrhoea), or less traditional signs
- For instance:
    - a decrease in the feed consumption at the pen level in a piggery may be considered as a sign of disease
    - an increase in antibiotic feed additive sales from a supplier may be another.

Syndromic surveillance involves the identification of specific signs or groups of signs, and analysis of the patterns of these signs, in space and time"

- the purpose is not to diagnose a specific disease, but to detect abnormal patterns of signs that may be due to one of a large number of diseases
- when an abnormal pattern is detected, a disease investigation follows, in order to diagnose the actual cause of the disease.

Patterns of signs and syndromes are often much less clear than direct diagnoses of disease:

- for instance, if diarrhoea were used as an indicator of the presence of classical swine fever a syndromic surveillance system may collect farmer reports of diarrhoea in their pigs (or alternatively, sales of treatments for diarrhoea)
- however, there are many causes of diarrhoea, so there would be a constant stream of reports coming into the surveillance system
    - a single case of CSF would just be one more report amongst the many others
    - however, CSF usually occurs as significant outbreaks, and can spread from farm to farm
    - while the normal pattern of diarrhoea reports may show a certain slightly varying level over time, when a new cause of diarrhoea enters the population (CSF), the pattern would change.
- in order to detect these changes, large amounts of data are required

    - this helps establish the normal patterns of the sign or syndrome being analysed
        - how much there is
        - any seasonal variations
        - any normal random variations in the absence of our target disease)
    - and makes it easier to spot a change in this pattern when the new disease appears.

The source of data for syndromic surveillance systems should normally be:

- fast
- simple
- cheap
- allow the routine collection of large amounts of data.
- for instance, commercial poultry farms expect a certain amount of mortality each day:
    - death is a syndrome which can be used to detect disease
    - commercial farms routinely record the daily mortality in their sheds
    - if this data was collected centrally for analysis, it could easily be used to detect unusual patterns of mortality in the population, and trigger a rapid investigation.

The above examples illustrate the three types of data that can be collected by a syndromic surveillance system:

1. individual signs
    - diarrhoea, fever, lameness, agitation, etc. are all clinical signs
    - some syndromic surveillance systems rely on farmers or veterinarians recording the clinical signs that they observe, without requiring them to make a diagnosis on the basis of these signs
    - patterns and combinations of the signs are analysed to
        - determine what is normal, and to
        - detect what is abnormal.
2. syndromes
    - rather than reporting each individual sign, some systems classify each case observed according to the dominant organ system involved
        - for example, the case may be classified as respiratory, gastro-intestinal or neurological
        - these classifications can be analysed to look for unusual patterns
            - death, in this case can be thought of as a syndrome.
3. indirect signs
    - are those signs that are not observed directly in sick animals, but are observed indirectly:

        - feed consumption
        - drug usage etc.

Objectives

The most common use of syndromic surveillance is as an early warning system for the detection of new emerging or exotic diseases:

- it is of particular value in the detection of previously unknown diseases
    - it is not seeking a particular diagnosis, simply an unusual pattern of signs
    - this means that a new disease that presents in an unpredictable way will be detected just as easily as a well-recognised disease
    - this is one of the advantages of syndromic surveillance over more traditional surveillance based on laboratory diagnoses
- it also can be used to monitor changes in the level and distribution of endemic disease, but this is less common.

Common problems

- the most common problem is the volume of data required to allow meaningful statistical analysis of patterns of signs
- analytical algorithms are required for pattern detection
    - these may be complex and require significant computing power
    - analysis should be continuous so that events can be identified as quickly as possible
- need for follow up of suspicious events
    - syndromic surveillance systems cannot make diagnoses
    - field investigations are required whenever an alarm is raised
- false alarms
    - the sensitivity and specificity of syndromic surveillance is related to the level that is set for the alarm
    - this depends on how 'unusual' a pattern must be before it raises an alarm
    - if only extreme events trigger alarms, then there will be very few false alarms, but there is a significant risk that a real, more subtle event will be missed
        - on the other hand, if the system is made too sensitive, there will be many false alarms which waste resources and undermine confidence in the system.

How to improve

- large volumes of data make syndromic surveillance systems work better
    - the more data that is available, the easier it is to define what is normal and to detect abnormal events

- effective data collection, communication, management and analysis systems will make it easier to handle large data volumes
- identification of appropriate, cheap indirect data sources can be useful
    - if there is a source of a significant volume of data that is already available in electronic format (e.g. production statistics from a large integrated company with many farms), this may serve as a valuable source of inexpensive data.
- where village animal health workers (VAHWs) do the reporting, constant training of the VAHWs should be done to upgrade skills in recognizing disease signs

Participatory Disease Surveillance

Participatory disease surveillance (or participatory disease searching, PDS) is a relatively new term to describe an approach to surveillance involving engagement of farmers. The methods arose out of earlier work on participatory epidemiology (PE), participatory rural appraisal (PRA). The common features of all these approaches are the use of trained teams to conduct semistructured or unstructured interviews with farmers, and the use of a variety of tools (such as participatory disease or risk mapping, brain storming, development of calendars, prioritisation or ranking exercises, and open discussions) to get an overall assessment of the problems and needs of the farmers.

Description

When participatory approaches are used for surveillance, the prime objective is still surveillance. This means that a key output is quantitative data on the occurrence of disease. The participatory approaches from which PDS evolved are specifically designed to allow investigators to get a general understanding of issues and problems from the point of view of the farmers, and to help address these problems without any preconceptions of what the most important issues might be.

PDS may be used in two ways. One is as targeted surveillance, investigating the occurrence of a single disease (examples include HPAI in Indonesia, or Rinderpest in Pakistan or Africa). This application is at odds with the participatory philosophy, as investigators have the prime concern of finding out about the disease of interest – while they may be happy to learn about disease in general from the farmers point of view, or indeed other problems, they are not in a position to do anything about the other problems.

The second approach is to use PDS as a general surveillance tool, in which case information about all diseases of importance to farmers can be collected, and used for prioritisation. However, the investigators are limited by their preconception that animal disease is a key problem, and the one that they are investigating.

Because PDS is a surveillance activity, rather than a component of a rural development activity, and its main reason is to collect data, it is better to separate it from the associated methods from which it evolved, and assess its value in terms of surveillance.

PDS is active surveillance. Trained teams visit villages and talk to farmers, and the reason they are doing this is to generate surveillance data. As discussed above, it may be general or targeted. The source of the information is the farmers, and the way data is collected is through discussion with the farmers. PDS may therefore be thought of as

an alternative approach to the farmer reporting system, that overcomes some of the key problems of that system.

In essence, PDS is the same as the farmer reporting system, but converts it from being passive (the farmer contacts the veterinary services) to being active (the veterinary services contact the farmer). This overcomes some (but not all) of the problems of low farmer reporting rates.

The participatory tools used in PDS should not be considered as something special for this activity, but simply a documented approach to collecting good information from farmers, that can and should be used (to the extent appropriate) whenever the veterinary staff are discussing disease issues with farmers.

Objectives

The objectives of PDS may be to:

- Find cases of disease (early detection)
- Demonstrate freedom from disease
- Evaluate the level and impact of disease for prioritisation

One of the advantages of PDS for case finding is that the villages of farms can be selected based on risk or prior information. Information gathered in one interview may provide clues as to the location of disease elsewhere (such as through trace forward or trace back information). This suspect location can then be investigated to track down cases of disease.

Common problems

PDS is active surveillance, and as such, it shares many of the problems of other active surveillance activities, including:

- Cost
    - Field teams have to be specifically employed, and need to get to the locations to talk to farmers
- Coverage
    - Unlike passive reporting, where most of the population is under observation, PDS can only cover those locations where the field teams visit.
- Representativeness

    - PDS may be able to provide representative data, depending on the way data is collected. In particular, two approaches may be used to select the locations of villages and farmers for interviews. The first is random selection (in which case the data may be more representative). The second is purposive selection, meaning that villages and farmers are selected as there is some reason to suspect that disease is present. This may be because of a passive report, or because they have been assessed to be part of a high risk group.

- Training
    - Field teams need to be well trained to use the participatory tools effectively.
- Farmer cooperation
    - PDS overcomes a number of problems of the passive reporting system.
- Timeliness
    - PDS normally collects retrospective data, based on the memory of farmers. Occasionally there may be a current outbreak in the village visited, but more often historical information is all that is available. This may be adequate when trying to demonstrate freedom from disease, but when cases that have occurred weeks or months ago it is often too late to implement any meaningful control or tracing.

Stages of surveillance - changing tests and surveillance objectives

Learning Objectives

After studying this chapter you should be able to:

- ☐ Recognise why surveillance requirements change over time
- ☐ Identify the aspects of a surveillance program that may be changed and the impact of different types of changes on the cost of surveillance and the effectiveness with respect to the program objectives
- ☐ Distinguish between the different phased approaches to surveillance that may be used for
    - Endemic disease control and eradication
    - Emergency disease response and eradication
    - Definition of zones
    - Trade support
    - Investigating new or emerging disease problems

Surveillance programs are never static, and should never be considered as 'perfect'. Changing disease situations demand that the approaches taken to disease surveillance are flexible and responsive.

The key driver in changing a surveillance program is the changing objectives of the program.

- the main ways in which we can respond are to vary the:
    - overall surveillance strategy
        - passive
        - active
        - general
        - targeted
    - tests used
- this can bring about a change in the costs associated with surveillance, and changes in the overall sensitivity and specificity of the program.

This section lists a number of example surveillance scenarios, and identifies the stages of surveillance that may be passed through, and the changing objectives.

Stages in endemic disease control and eradication programs

1. identify the problem
    - general, relatively inexpensive surveillance is initially required to identify that the disease exists and that it may represent a problem
    - moderate sensitivity and specificity are adequate at this stage
2. establish the extent of the problem
    - once the problem has been identified, surveillance may switch to targeted, but should still be relatively inexpensive.
    - the aim is to identify the distribution and level of disease, but there is no need for great precision at this stage.
    - the results of this surveillance will be used to decide if a control program is warranted.
    - again sensitivity and specificity should be moderate
3. decide on the control policy
    - when planning a control program, there may be a number of specific questions that need to be answered
    - more focused surveillance may be required, in addition to other research
        - for instance, identification of risk factors for disease
4. early control
    - normally, during the early stages of a control program, the main activity is focused on decreasing the level of disease to a manageable level
    - surveillance at this stage may involve evaluation of the progress of the control program, and the effectiveness of specific control measures
        - for instance, if vaccination is used, surveillance may evaluate the level of population protection achieved by the vaccination program
    - the surveillance will be closely tied to the control program at this stage, as much surveillance information can be gathered during control activities
    - high sensitivity is required, but the program can tolerate moderate specificity
        - this is because the implications of a false positive are not too costly
5. later control and eradication
    - as the program progresses, the level of disease should decrease
    - the focus will shift from population-level interventions to identifying remaining problem areas and case finding
    - surveillance will shift to an early warning and response approach
    - while sensitivity is still important, a high specificity is now required

        - this is because, as the level of disease decreases, most positives are likely to be false positives and the cost of destruction of healthy animals can become very high
6. final eradication
    - at the end of the program (or phased during the program if progressive free zoning is used), areas or the country will become free from disease
    - surveillance at this stage is required to demonstrate freedom from disease
    - high sensitivity, and adequate specificity to avoid an unacceptable number of false alarms
7. maintenance of freedom
    - once freedom is demonstrated, surveillance can switch back to routine early warning and detection systems.

Stages in emergency disease response and eradication

1. determine magnitude of the problem
    - if there is an outbreak of an exotic or emergency disease in a previously free area, it is important to first determine the extent of the problem as quickly as possible
    - extremely rapid assessments should be made using tests that:
        - may not be very highly sensitive or specific
        - but which can give a quick picture to help plan the response
    - positive cases should be rapidly followed up to achieve reasonably high specificity
    - the areas under surveillance should vary
    - a heightened level of general passive surveillance should be immediately introduced across the country
    - intensive targeted surveillance should start at known outbreak locations and then move to other locations on the basis of risk
        - this may involve other areas that are close by or contact premises due to livestock movements
2. eradication phase
    - in a major outbreak, the surveillance in a known infected area normally has:
        - very highly sensitive
        - only moderate specificity
    - for instance, clinical diagnosis of the disease is adequate to confirm a farm as being infected and warrant destruction
        - this is a very unusual situation, and is required due to:
            - the need for great speed when controlling an emergency disease and
            - the problem with overloading laboratories with too many tests if all suspect farms were confirmed with laboratory follow-up.

3. final eradication
    - after the disease has been eradicated, the same surveillance as described above is required:
        - for demonstration of freedom, and
        - early detection of new incursions.

Stages in definition of zones

1. initial surveillance to identify possible areas for zones
    - targeted surveillance with moderate sensitivity and specificity can be used to get a broad picture of the distribution and level of disease.
    - only low precision is required to identify initial candidate zones
2. determining if proposed zone is free or not
    - when a potential zone has been identified, more detailed targeted surveillance with increased precision is required
3. eradication if it is not free
    - if the zone is found to have low levels of disease, an eradication program is started with surveillance requirements similar to those outlined above for endemic diseases.
4. demonstration that it is free when eradicated
    - after completion of the eradication, surveillance for freedom from disease is required
5. maintain freedom/early detection
    - as a zone is normally at greater risk from disease incursions than an entire free country (due to the non-free areas surrounding it), a higher level of surveillance is required for
        - early detection and
        - ongoing demonstration of freedom from disease.

Stages in routine reporting for trade support

Ongoing surveillance

- if the country is free:
    - ongoing surveillance is required to provide:
        - early warning capacity but also providing
        - continuous evidence of freedom from disease
    - many sources of data can contribute evidence of freedom including:
        - absence of reports from farmer reporting systems
        - structured negative reporting systems
        - abattoir surveillance etc
- if the country is not free:
    - there may still be requirements to report the level of disease to trading partners, to support import risk analysis

- the structure of this surveillance will depend on the requirements of the trading partner
- if precise information is required, special-purpose surveys may need to be carried out
    - more often, a combination of potentially-biased data sources is adequate, such as:
        - farmer reporting
        - abattoir surveillance.

Stages in the investigation of emerging or new disease problem

1. detection of the problem
    - early detection and warning, normally through a farmer reporting system, is required to detect, initially, that there is an unusual problem
    - targeted investigations may follow this
2. characterisation of the problem
    - if the problem is new, the cause of the problem may not be immediately obvious
    - surveillance can assist in determining the cause, by:
        - collecting data on disease occurrence (using a case definition), and
        - targeted surveillance for potential risk factors.

Managing surveillance data

Learning Objectives

After studying this chapter you should be able to:

- ☐ Select the most appropriate type of software for managing surveillance data
- ☐ Understand the role of various global, regional and national animal health information systems.

Recording and reporting surveillance data

Most countries use a variety of systems for recording and managing their surveillance data. These range from paper-based reporting and filing systems to spreadsheet systems and specially designed databases. Whichever system is used, it is important that data is accessible and easily analysed to support decision-making. There will also be occasions when surveillance and data management systems will be reviewed, for example as part of an evaluation of a country's veterinary services. The **accessibility** and **accuracy** of the data is therefore critical.

Full consideration of structure, development and operation of an animal health information system is beyond the scope of this volume. This chapter aims to highlight some of the major systems in use. A more detailed discussion of aspects of disease reporting in a farmer reporting system has been given in the previous chapter (see page 78 and following).

Member countries of the OIE are also required to report regularly on disease occurrence for 'listed' diseases in their country. The frequency of reporting and level of detail will depend on the disease and the country's disease status. This means that there needs to be a mechanism for analysing and collating data from field surveillance activities in a timely manner for international reporting, as well as for national management of disease. This may require analysis at multiple levels for different purposes, as shown in the table below.

Table 3: Information needs at different operational levels.

Operational Level	Information needs
Local animal health managers	Detailed information for day-to-day disease control activities
Regional or Provincial Managers	Provincial statistics on progress and difficulties
National Managers	Summary statistics for overall program management, budgeting and international reporting

Software for data management

Animal health information systems are often large and complex systems, developed by experts in information technology. However in some cases, simpler systems may be adequate for specific components of an information system. When developing a system, there is a choice of software that may be used.

Spreadsheets

Spreadsheets (such as Microsoft Excel) are available on virtually every computer, and are very simple to use. Recording data on a spreadsheet simply involves typing the data items with

- each record (e.g. case or event) on one row, and
- each data item (e.g. date, diagnosis) in a separate column.

Spreadsheets are appropriate to rapidly record small amounts of data, such as obtained from a special survey, as they require virtually no set-up time, and are easy to use.

However, they are not suitable for large data sets or routine use within a permanent information system. This is because:

- they have virtually no capacity to control data quality
- their analytical capabilities are very limited
- they are not able to manage extremely large amounts of data

- they are not able to effectively maintain relationships between different data types (for instance, lists of villages, lists of vaccines and records of vaccinations carried out)

Databases are able to overcome all of these disadvantages.

Databases

Databases are specifically designed to manage the type of data that is collected by an animal health information system, and should be used whenever possible.

Setting up a database involves defining the type of data to be stored, and creating screens to submit that data. This process is more complex and time consuming than setting up a spreadsheet. However, database are able to:

- control the quality of data submitted
    - for instance, if a field is meant to store the age of animal, the database can be set to only accept numbers, and only in a range that is reasonable.
    - If a field is meant to store the diagnosis, a separate list of standard diagnoses can be established, and the system can limit users to selecting from this list. This ensures standardisation and prevents the same diagnosis being entered under two different names.
- Handle very large volumes of data and process the data rapidly
- Rapidly perform the normal types of analysis and reporting required

There are many different database programs available. These can be divided into systems that are designed to run primarily on a single computer (stand-alone systems) and those that are intended for use on a network.

Examples of stand-alone systems include:

- Microsoft Access.
    - A commercial general database system.
- EpiInfo.
    - This is a specialised database system designed specifically for epidemiological analysis.

    - It integrates specialised analytical tools to help with epidemiological analysis.
    - More information and free downloads are available from http://www.cdc.gov/epiinfo/

Databases for use on a network are more complex, and general require separate software to develop specialised interfaces for submission of data, reporting and analysis. The advantage of these systems is that they can be installed on the internet and accessed by a web browser. This means that any user with internet access can submit data directly into a central database, without the need to have specialised software installed on their own computer.

Examples of these types of databases include:

- Oracle
    - Commercial, very powerful, very expensive
    - http://www.oracle.com
- MySQL
    - Free version available, very powerful.
    - http://dev.mysql.com
- Microsoft SQL Server
    - Commercial, very powerful, very expensive.
    - http://www.microsoft.com/sql/default.mspx

Interfaces to these databases can be developed using many different software packages including:

- PHP
    - free, powerful web scripting software
    - http://www.php.net
- Microsoft ASP .net
    - http://msdn2.microsoft.com/en-au/asp.net/default.aspx

Statistical analysis packages

A database and an interface is all that is required to run an effective system. However for more detailed or complex analysis, or for the production of graphs, it is often necessary to use a specialist statistical package. As with databases, these can be stand-alone packages to do interactive one-off analysis, or they can be systems that are integrated into a server, allowing users on the internet to perform the analysis on demand.

Example software includes:

- R statistical environment:
    - free, very powerful, good graphics,
    - able to be integrated with a database on the internet
    - complex and difficult to learn
    - http://www.r-project.org/
- SAS
    - Commercial, expensive, very powerful
    - http://www.sas.com
- Stata
    - Commercial, powerful, expensive
    - Primarily for stand-alone use
    - http://www.stata.com
- EpiInfo
    - Although primarily a database, it is also very useful for epidemiological analysis, and has a simpler interface
    - Free
    - http://www.cdc.gov/epiinfo/

Geographical information systems and mapping software

The presentation of data is an important part of the function of an animal health information system. Much data can be summarised and reported as tables or graphs, but maps play an essential role in understanding the distribution of disease. It is therefore common for systems to incorporate mapping functions. Examples of suitable software include:

- ArcGIS
    - Commercial, powerful expensive
    - Relatively easy to learn to use
    - Usually used as stand-alone software but can be integrated into an automated system
    - http://www.esri.com
- MapInfo
    - Similar commercial package to ArcGIS
    - http://www.mapinfo.com
- Mapserver
    - Free dynamic map generation software for integration into a web-based information system
    - Complex to learn and implement
    - http://mapserver.gis.umn.edu
- uDig
    - Free desktop and internet enabled GIS software
    - http://udig.refractions.net/confluence/display/UDIG/Home

Examples of animal health information systems

Many countries run their own internal systems for managing surveillance data. However, there are now a number of systems available for countries wishing to use them to support reporting and analysis of surveillance data. These systems may operate at the global, regional or national levels.

Global information systems

WAHIS and WAHID

WAHIS (World Animal Health Information System) now allows OIE Member Countries to report disease occurrence to the OIE directly using the *WAHIS* Web application instead of using paper forms (as in the past). The *WAHIS* interface supports submission of immediate notifications and follow-up reports, six-monthly reports and annual reports for 'listed' diseases, as required by the OIE. Data submitted through WAHIS is stored on-line in a secure database. This data can then only be accessed by the submitting country or by the OIE for reporting and analysis.

In addition, summary output from the *WAHIS* system is now publicly available through the *WAHID* Interface, providing access to the World Animal Health Database, allowing end-users a wide range of queries on a given country or region, or two or more countries or regions, all with mapping support.

More information on WAHID can be obtained at:

http://www.oie.int/wahid-prod/public.php?page=home

Regional information systems

ARAHIS

To assist ASEAN countries meet their reporting responsibilities, the ASEAN Regional Animal Health Information System (*ARAHIS*) was developed in 2005-06 as part of a project aimed at strengthening animal health and biosecurity in the ASEAN region.

ARAHIS is an internet-based regional disease reporting system and is closely integrated with the new OIE *WAHIS*. Any data entered by ASEAN member countries into *ARAHIS* will be able to be automatically transferred to the OIE system, avoiding duplicate data entry and inconsistencies.

It was developed with the objectives of:

- Allowing rapid, free and secure sharing of data between member countries
- Removing duplication of reporting obligations. The system incorporates the functions and capability of a number of existing systems, including the OIE global reporting, Tokyo office reporting, FMD regional reporting, and AHPISA.
- Provides new capacity to support developing disease control programs, such as regional Avian Influenza reporting.
- Providing early warning of potentially important disease outbreaks

The system manages two main types of data, disease and non disease data. ASEAN members have currently selected 4 diseases of importance for regional reporting:

- Foot and mouth disease
- Avian influenza
- Classical swine fever
- Newcastle disease

However, the system can be quickly and easily expanded to include any number of diseases. Disease reports are outbreak-based, and data collected matches the data required by the OIE's immediate notification system.

Non-disease information provides background data to help interpret the disease information. It is based on (but extends) the requirements of the OIE annual report, and includes data on:

- Animal Populations
- Livestock movement
- Vaccination campaigns
- Personnel
- National contacts
- Veterinary infrastructure (laboratories, checkpoints, quarantine stations, as well as markets and slaughterhouses)
- National notifiable disease lists
- Laboratory capability
- Key regional and national documents and standards

Outputs of the system are presented in both tabular and map form, and will be progressively refined in response to the changing user requirements.

ARAHIS can be found at: http://www.arahis.oie.int/

AHPISA

The Animal Health and Production Information System for ASEAN countries (*AHPISA*) was established in 1989 with the aim of strengthening and harmonizing animal health and production information systems in its member countries. Specific objectives of *AHPISA* are:

- Strengthening disease control
- Facilitating trade and
- Protecting human health

Currently the AHPISA database records data on disease outbreaks entered by member countries. However, data is incomplete and the system has not been well-supported by all ASEAN members. For the future, it is anticipated that *AHPISA* will provide a public portal for access to data stored in *ARAHIS*.

National information systems

All countries have some form of information system to manage data on animal diseases. Usually, these have developed over many years, and are designed to integrate with national protocols and requirements. Some of these systems are highly developed and very effective, while others have grown in an *ad hoc* way, are under-resourced and ineffective.

For countries that have not developed an effective national information system of their own, FAO has developed a model information system which may be adapted to the national needs of any country.

TADinfo

TADinfo is a unique veterinary data management system developed by the FAO and currently used in nearly forty countries worldwide. *TADinfo* provides an off-the-shelf software package for animal disease quantification and management for use in developing countries which do not yet have the expertise – or perhaps the time – to develop their own software. *TADInfo* is used for management of disease outbreaks, while *ARAHIS* and *WAHIS* are used to manage reporting of disease incidents to the OIE (see below).

TADinfo was developed as part of FAO's EMPRES (*Emergency Prevention System for Transboundary Animal and Plant Pests and Diseases*) programme to provide data

management and decision support to national veterinary epidemiology units. It combines the power of the Microsoft Access relational database system, and an industry standard geographic information system, ArcView. Importantly, *TADinfo* has been designed with flexibility, adaptability and extensibility in mind. It offers a set of simple to use tools that are applicable in most situations and a high degree of flexibility in options for analysis of data.

TADinfo makes use of a number of data sources traditionally available in developing countries, including:

- passive observation of disease occurrences by veterinary and paraveterinary staff;
- active disease surveys;
- abattoir/slaughter data;
- livestock census and
- vaccination data.

More information is available at:

http://www.fao.org/ag/againfo/programmes/en/empres/tadinfo/about.html

Analysis and Use of Surveillance Data

Learning Objectives

After studying this chapter you should be able to:

- ☐ Assess the key factors required to plan data analysis
- ☐ Understand the impact of the following factors on the choice of data analysis
  - Objective of the surveillance
  - Representativeness of the data
  - Importance of the decision
  - Tests used
  - Sample and population sizes
  - Assumptions
- ☐ Select the appropriate type of analysis when using representative data for
  - Detecting or demonstrating freedom from disease
  - Measuring or describing disease

This section provides some general guidelines on the analysis and use of surveillance data:

- detailed guidance in the analysis of data from all different types of surveillance is beyond the scope of this book
- users should refer to other texts referenced in this manual for more detailed information.

Factors to consider when analysing surveillance data

Objective of the surveillance

A clear understanding of the objective of the surveillance, and in particular, the key question that is being asked, will assist in determining the appropriate type of surveillance.

For instance, if the objective is to demonstrate freedom for a zone:

- the question would be *Is this zone free from infection?*
- the apparent answer is yes or no

- however, as it is not possible to definitively prove that there is no infection present, the answer has to be expressed in terms of probability
- the analysis, therefore, is one which will assess how likely it is that infection would have been found by the surveillance, given the amount of sampling that has been done, and an assumption about the level of disease that would be present if the infection were present in the population.

On the other hand, if the objective is to detect incursions of exotic disease, and to launch an emergency response:

- little analysis may be necessary, once a positive case has been identified
- if any analysis is done, it may involve:
    - determining the probability that a positive result is due to a truly positive animal and is not in fact a false positive (i.e. calculating the positive predictive value of the test system), and
    - perhaps an assessment of the relative costs of a) doing nothing if it is positive and b) launching an emergency response if it is actually a false positive
        - in reality, these types of calculations should have been done in advance.

Representativeness of the data

Very different approaches need to be taken when analysing the following different types of data:

- representative data
    - e.g. collected in a structured survey using random sampling
- non-representative data
    - e.g. collected through a 'convenience' surveillance process.

These different approaches are discussed below.

Importance of the decision

The time and effort put into the analysis depends partly on the importance of the output of that analysis:

- for instance, if a major export opportunity depends on the results of the surveillance, and this export market could be worth many millions of dollars of income for producers, then it is worth doing a detailed analysis to ensure:
    1. that the correct result is reached and
    2. that there can be no criticism or doubt about the approach that was used

- on the other hand, if there is little economic benefit likely, and no major decisions depending on the analysis, a quicker, less complex approach may be justified
    - one must always consider, if the results are not important, why the surveillance is being done at all.

Tests used

In almost all cases, the estimated performance of any tests used should be taken into account:

- much analysis of surveillance data in the past has been based on the **incorrect** assumption that tests are perfect (sensitivity and specificity are both equal to 100%)
- for instance, the prevalence of disease is estimated by dividing the total number of positive test results by the total number of animals tested
    - depending on the test characteristics, this may over- or under-estimate the true level of disease

Often the exact values for sensitivity and specificity are not known. This leaves three options:

1. assume that they are perfect
    - this is a bad option, and should not be done
2. seek estimates
    - from the literature
    - other experienced users
    - other laboratories
    - guess based on your own experience
    - this is not a great option, but better than assuming the tests are perfect
3. find out what the true performance of the tests is in your own environment, by:
    - conducting validity studies, or
    - using newer approaches that do not require a gold standard
        - this may be possible simply using existing laboratory records.

Number of animals examined or tested, and the results of the testing

These are clearly important numbers when analysing surveillance data.

The size of the population studied

Many types of analysis of surveillance data require information on:

- the number of animals affected
    - the *numerator* or number on top
- number of animals at risk

    - the *denominator* or the number on the bottom.

Calculating prevalence is the simplest example of these analyses:

- prevalence is equal to (total animals affected)/(total animals at risk)
- this denominator is important in the calculation but can be hard to know exactly what number to use.
    - the total number of animals at risk is often considered to be the size of the total population, but there are a number of different definitions of *population* that must be considered.

Populations defined:

- *reference population* or *population of interest*
    - this is the population that we wish to understand
    - our surveillance is intended to provide answers about this population.
    - for instance, it may be all the cattle in the country.
- *study population*
    - this is the population that is involved in the surveillance (or some other type of study).
    - ideally it is the same as the reference population, but often it is not.
    - for instance, the study population for abattoir surveillance of pigs may be all pigs that are slaughtered during a specific time period, which is very different to the reference population which may be all the commercial pigs in the country.
- *sample (population)*
    - this is the group of animals that is actually examined (or from which some data is collected).

The relevant populations and groups for numerators and denominators vary according to the type of surveillance:

- a *structured survey*
    - the denominator is the total sample size, or simply the total number of animals tested
    - the numerator is the number of positive animals detected (or animals with the characteristic of interest)
    - the study population is the population from which the survey drew its sample. It is normally defined by the sampling frame.
    - the the difference between the study population and the reference population may be due to imperfect sampling frames (for instance, only farms with more than a certain number of pigs may be registered, and therefore appear on the sampling frame). The survey results may be applicable to the study population, but may not apply to all parts of the reference population.

- *abattoir surveillance*
    - the denominator may be the same as the study population, the total number of animals that pass through the abattoir in a given period, or if sampling is used, it may be only those animals in the groups that were examined (the sample)
- *farmer reporting systems*
    - the denominator may be the total number of animals in the entire population (the reference population), or
    - it may be necessary to exclude some animals that are not being routinely checked (the study population).
        - e.g. exclude animals that are left grazing in the wild for long periods.

Other assumptions

Some types of analysis require other assumptions.

A common example of this is the analysis of surveillance data to demonstrate freedom from disease:

- this is based on an assumption that, if disease were present, it would be at a specified level (the *design prevalence)*
- these other assumptions should ideally be set by agreed standards, but otherwise should be carefully justified.

Guidelines for the analysis of surveillance data

Measuring level or distribution of endemic disease

- the key type of analysis when measuring disease is to calculate the *prevalence* of disease; however, this is just the most common of many possible types of analysis.
- determining the *distribution* of disease involves measuring the level of disease (usually using prevalence) in different areas.
- for some diseases and situations, *incidence* is a more useful measure.
- more complex analysis may also be possible, to examine risk factors and associations.

Representative data

When data is *representative* of the population from which it was drawn (for example, because it is a census with information from every member of the population, or because it was collected with a structured survey using random sampling)

- then it is usually possible to analyse the data either:
    - based on the fact that there is no bias present, or

    - taking into account any bias that is present
        - this may done with some complex sampling approaches.
- methods for the analysis of this type of data are described in *Survey Toolbox for Livestock Diseases*, Chapter 7 (page 149).

Non-representative data

The key difficulties with non-representative data, such as that produced by abattoir surveillance or a farmer reporting system, are that:

- it is likely to be significantly biased, and
- it is not possible to use traditional statistical formulae to validly calculate even simple results such as prevalence or precision.

A number of solutions have been used to overcome this problem:

1. treat the data as if it were representative
    - this is commonly done and is very dangerous
    - the bias means that any results are likely to be wrong, and as a result, any decisions made on the basis of this data could be wrong
    - wrong decisions risk wasting money and having no impact (or worse, a negative impact) on the disease situation
2. recognise that any results are biased, but assume that these biases are constant over time
    - using this approach, one may calculate the incidence of haemorrhagic septicaemia to be 2.5 cases per 1000 animals per year (using the techniques described in *Survey Toolbox*)
    - one would recognise that this may not be correct
        - however, by conducting regular surveillance each year, any change in this level could indicate a change in the real level of disease
    - this approach is better, but still dangerous.
        - in a non-representative system, such as a farmer reporting system, there are many factors that may result in a case being reported or not reported (and therefore influencing the bias in the results).
    - while many of these factors may remain relatively constant (some farmers in remote areas will always find it hard to report), others change over time
    - for instance, if there has been a recent, well-publicised outbreak, the level of farmer awareness may increase
        - similarly a change in staff may mean that the new veterinary officer prefers to spend more time visiting villages, increasing the reporting rate

        - as a result, an increase in the number of reports of disease may be due to an increase in the level of disease, or just a change in reporting rate due to many different factors
3. try to guess what the biases are and take them into account.
    - if the surveillance system is well understood, it may not be possible to determine exactly what all the biases are, but it may be possible to determine the direction of the major biases
    - for instance, with abattoir surveillance, it is less likely that sick animals will be presented to the abattoir
        - Therefore, any estimate of the prevalence of disease based on abattoir sampling is likely to be biased, but we can assume that it is an *under-estimate* of the true level
        - This would indicate that the value measured is less than the true value
        - This information may be enough to support valid decision-making
    - for instance, if it is calculated that the benefit of a control program would outweigh the benefits, given a disease prevalence of 10% or higher, and abattoir surveillance shows a prevalence of about 10%, then we can be confident that the true prevalence is higher, and that a control program should be introduced.
4. use complex modelling approaches to try to describe and take into account the known sources of bias
    - these techniques are new, complex and require computer modelling skills
    - this is not a practical option for most situations

Demonstrating freedom from disease

The analytical techniques for demonstrating freedom from disease are different to, and somewhat more complex than, those used for measuring the level of disease:

- this is mainly due to the fact that it is impossible to prove that disease is not present
    - so we need to use probabilistic approaches based on the assumption that it is present at a specified level.

Representative data from simple surveys

The background to this type of analysis and details of how it can be conducted are described in *Survey Toolbox*, Chapter 9 (page 189).

Non representative data, multiple data sources, data over different time periods

Recent research has developed new modelling techniques for the analysis of non-representative data to help demonstrate freedom from disease.

- as described above, this technique requires computer modelling skills.
- the method is described on a dedicated web site at http://www.ausvet.com.au/freedom.
- the web site includes on-line software that simplifies the modelling process.

Other useful tools are available:

- these allow the combination evidence from multiple different data sources to produce an overall estimate of the probability of freedom.
- similar tools allow evidence from multiple time periods to be taken into account, discounting the value of older data.

Evaluation and Improvement of Surveillance Systems

Learning Objectives

After studying this chapter you should be able to:

- ☐ Understand the application of HACCP and audit approaches to quality assurance of a surveillance system
- ☐ List key quality indicators of surveillance system
- ☐ Understand how to measure the quality of systems to demonstrate freedom from disease
- ☐ Understand how to measure the quality of systems to measure disease
- ☐ Apply relevant methods to decide on the appropriate amount of surveillance

Introduction to evaluation of surveillance systems

Surveillance systems are often complex:

- the system used to gather information about a particular disease may have several different components:
  - abattoir surveillance
  - farmer reporting
  - structured surveys
- some components may be highly structured and representative, while others are targeted, and yet others are biased.

Having a system to collect surveillance information is clearly useful. However, that is normally not enough. It is important to understand how **good** the surveillance system is. Usually, this is related to economics:

- there is usually a limited budget available for animal health
- there are many competing demands on this limited budget, such as:
  - disease control
  - regulation
  - extension
  - surveillance

In order to decide how much of the money should be spent on surveillance, and whether that money is being spent well, we need to understand how good the surveillance is. The main questions are:

- is the surveillance meeting our objectives in providing the right information for decision making?
- is the current approach to surveillance the most cost effective way of collecting this information?

Note that for both these questions, the starting point is an understanding of the objectives of the surveillance: how will the data be used? A clear understanding of the objectives of the surveillance provides the standard against which we can measure the surveillance.

Features of a surveillance system

When evaluating a surveillance system, there are a number of different features that need to be taken into account. These features can be divided into two groups:

1. *what* data is collected
2. *how* that data is collected.

Data quality

An evaluation of the data collected involves assessing the **quality** of the data:

- this is concerned with working out how well the collected data is able to meet the objectives of the surveillance and assist decision makers
- the ways in which data quality are measured depends on the purpose of surveillance, whether it is to:
    - demonstrate the absence of disease
    - measure the level of disease
- these two cases are discussed in detail later in this chapter.

Quality assurance

Another aspect of data quality is related to **confidence**.

For example, we may have:

- collected a large amount of samples
- analysed them to produce test results
- analysed the data
- arrived at a conclusion about the population

Perhaps we have taken into account some potential biases in the way the data is collected. However, our final conclusion will only be correct if our understanding of the way the data was collected is correct.

For instance, if we believe the data was collected by randomly sampling 20 animals per village, our analysis will reflect this. Yet if the survey teams actually took 20 identical blood samples from a single animal (to save time), then our interpretation will be wrong.

Similarly, if we believe the lab is using a particular test with high sensitivity and specificity, but in fact they are using a cheaper but less reliable test, our conclusions will again be wrong.

The quality of the surveillance system therefore is related to our confidence that the system is operating as it is intended to.

We can get this confidence in a number of ways:

- perhaps the surveillance is run by highly trained individuals, all of whom we know personally, and we are therefore sure that they are doing the right thing
    - this would make us very confident that the procedures are being correctly followed
- more often, surveillance uses a large and unknown network of staff and contributors, whom we don't know
    - from time to time, even trained fields teams may be tempted to change their procedures for convenience.

In order to have confidence in a large surveillance system, some sort of **quality assurance procedures** should be developed:

- a quality assurance system is a bit like a surveillance system for a surveillance system
    - it aims to collect objective data to ensure that the procedures that are meant to be followed are actually being followed
- there are a number of approaches to running a quality assurance program for a surveillance system, involving different levels of expense and activity:
    - the highest level of assurance comes by double checking and documenting every step in the procedure, but this is time consuming and expensive
    - the appropriate level of quality assurance is usually determined by assessing the balance between cost and the need for objective measures of data quality
    - if the use of the surveillance data does not require these objective measures, quality assurance procedures can be simple, or may be absent.

Examples of quality assurance procedures

HACCP

One useful methodology for quality assurance is the *Hazard Analysis and Critical Control Points* (HACCP) approach:

- this involves critically analysing the process of the surveillance system and identifying *hazards*
    - in this case, hazards are points at which the operation of the system may depart in important ways from the procedures specified.
    - for instance, if surveillance requires random sampling of animals, there is a risk that field teams may use non-random approaches:
        - if ELISA is the test that should be used, it is important not to use a different test.
- for each of these hazards, a *critical control point (CCP)* is identified
    - the CCP is an indicator that the correct procedure has been used.

Examples of the HACCP approach:

- animals have been sampled using random sampling:
    - proof of this is notoriously difficult to find
    - if random numbers and a sampling frame are used:
        - one approach may be to provide copies of the original numbers and sampling frame specifying the animals to collect
        - alternatively, associated data could be collected from each animal (such as its age, sex, location)
            - later analysis of the data could be used to check if the distribution of these characteristics is consistent with a random sample or indicates that there is bias in the system.
- ensuring that each blood sample comes from a different animal:
    - in addition to measuring the characteristic of interest (e.g. antibody levels), some other variable characteristic could be (cheaply) measured from the blood
        - packed cell volume (PCV), or
        - a key electrolyte concentration (e.g. [Na+])
    - this could be analysed to determine if the distribution obtained from the population either:
        - is consistent with a random sample, or
        - shows evidence of bias
    - if multiple samples had been taken from individual animals, the resultant distribution would show peaks where all the values are the same for that animal, rather than a smoother distribution indicating the normal variation between animals.
- correct test performed:

- a CCP for the test performed may consist of retaining the raw optical density output from the ELISA plate reader, including positive and negative controls, to demonstrate that the ELISA was the test used and that it was performing correctly.

Audit-based systems

HACCP requires that records for each CCP are generated, retained and checked regularly. A less intensive approach is based on *auditability*:

- the same approach as HACCP to keeping records is used, but these are not routinely checked
- instead, the system ensures that enough records are retained to ensure that all steps can be confirmed to be operating correctly, if that system should be audited
- periodic audits are carried out to check the records.

Audit-based systems involve less expense, as verification is periodic rather than continuous:

- this means that the measures used to ensure that the procedures are correct can be more expensive than in a continuous HACCP system
- for instance, an audit system may involve a visit by the system auditor to a village where animals have been sampled, and discussions with the livestock owners to determine which animals were bled and how they were chosen
    - this is affordable when done every now and then, but would cost too much to be used routinely.

Audit systems depend on the knowledge that procedures *can* be checked, even if they rarely are.

Data collection systems

In addition to the data quality and quality assurance systems described above, there are a number of other key factors that need to be taken into account when evaluating a surveillance system, related to how the data is collected:

- the best quality data may be desirable, but if it is impractical to collect it, less perfect data may be adequate

Some of the other key factors include:

Cost

- the overall cost of the surveillance system is one of the most important aspects in evaluating the system

- many other factors are expressed through cost
- the cost of the system can be determined in a number of different ways
- in most cases, it is probably appropriate to consider only the **direct** costs of collecting the surveillance data to the organisation using the surveillance information:
    - this means that if some paid activities are for surveillance as well as other purposes, only a proportion of the costs should be counted
    - if costs are incurred by others outside the veterinary services, these may be considered.

Speed

- surveillance data should be available in a timely fashion
    - this means that it should be available when it is needed
- for some purposes, such as early detection, this means that surveillance data should be available almost immediately
- in other cases, such as routine reporting of the level of disease for international reporting obligations, timeliness is determined by the reporting schedules of the international reporting:
    - for instance, if reports are due three months after the end of the annual reporting period, this delay is acceptable.

Sustainability

- surveillance is normally an ongoing activity
    - some surveillance activities may be stopped, and new ones may be introduced, while intermittent cross sectional surveys may also be used
- however, one of the key things that distinguishes surveillance from a one-off research activity is the ongoing nature of surveillance
    - any surveillance activity must therefore be designed in a way such that it will be able to continue in the foreseeable future.
- sustainability depends on many things, and only a few of these are mentioned here
    - financial sustainability means that the funding mechanism for the surveillance is likely to be able to continue in the future
        - if it is funded out of recurrent government funds, then this is likely
        - if it is funded from a one-off grant, its future may be unsure
    - participant and public perception are also important in sustainability
        - if a farmer disease reporting system involves destruction of the entire herd without compensation when a certain disease is reported, the system will not be sustainable – farmers will quickly stop reporting
        - public perception can be important as well

        - consider a wildlife surveillance program that involves killing animals to assess their disease status
        - while low levels of sampling may be scientifically justified if the wild populations are relatively abundant, public perceptions may demand that killing wildlife in this way is stopped.

Resources

- in addition to financial resources, consideration of other resources is important when evaluating a surveillance system
- in particular, consider the availabilities of:
    - staff
    - transport
    - laboratory facilities
    - data management facilities
    - communication systems
    - couriers

Efficiency

- this is a somewhat vague concept, but involves a balance between the value of data collected, the cost and the use of resources
- for instance, abattoir surveillance may be considered to be very efficient, as a large number of samples can be collected rapidly at low cost at the one location, even if the samples are not representative of the general population
- on the other hand, sampling animals in villages may not be as efficient due to the time and cost of visiting each village
    - this inefficiency may well be balanced by the higher value of the surveillance data collected.

Frameworks for evaluation of surveillance

The process of evaluating a surveillance system may be undertaken for two distinct reasons:

1. to determine:
    - if the system is meeting its objectives
    - if there are weaknesses in the system
    - if there are opportunities for improvement
2. to assess the quality of one system in reference to another
    - this requires that the approaches used to evaluate the systems being compared are the same
    - in international trade, it is often necessary to assure trading partners that the surveillance systems used to determine disease status are of

adequate standard, and standardised approaches to the evaluation of surveillance systems have been developed to meet this need
    - Salman M, Stark KD and Zepeda C. (2003, full paper included on the CD) describe some of these approaches.

Broadly, there are two aspects to the evaluation of surveillance systems:

1. a quantitative assessment of the quality of the data that is produced by the surveillance system
    - the methods for this are discussed in the next section
2. a qualitative assessment of the rest of the aspects of a surveillance system
    - Salman et al. (2003) cite a list of criteria that can be used:

Table 4: Criteria for assessing the performance of a monitoring and surveillance system

Criterion	***Function***
usefulness	describes the contribution of the system to the prevention and control of diseases
simplicity	describes the ease of operating the system; surveillance systems should be as simple as possible while still meeting their objectives
flexibility	describes the ability of the system to adapt to changing information needs or operating conditions with little need for additional time, personnel or allocated funds
quality of data	refers to the completeness and validity of the data recorded by the surveillance system
acceptability	reflects the willingness of people and organisations to participate in the surveillance system
sensitivity	refers to the proportion of cases of a disease (or other health-related event) detected by the surveillance system alternatively, sensitivity can refer to the ability to detect outbreaks, including the ability to monitor changes in the number of cases over time
predictive value positive	proportions reported cases that actually have the health related event under surveillance
representativeness	describes the occurrence of a health-related event over time and its distribution in the population by place and species

timeliness	reflects the speed between steps in a surveillance system
stability	refers to the reliability (the ability to collect, manage and provide data properly, without failure) and availability (the ability to be operational when it is needed) of the surveillance system

They go on to cite an example of a scoring system to assess different aspects of a surveillance system, based on the following criteria and scores:

Table 5: A scoring system to assess the quality of a monitoring and surveillance system for exotic diseases

Element	Maximum score
1 aims	15
2 sampling	20
3 co-ordination and awareness	15
4 environmental factors	4
5 screening and diagnosis	20
6 data collection and transfer	10
7 data processing and analysis	10
8 information dissemination	6
Total	**100**

The scores in this approach provide a somewhat arbitrary assessment of the relative importance of each of the different elements in a surveillance system:

- the difficulty with such a system is that it cannot be simply applied to the full range of different surveillance activities
- however, modified versions may be able to be used.

Detailed descriptions of approaches to the evaluation of surveillance systems can be found in:

- Salman M, Stark KD, Zepeda C. *Quality assurance applied to animal disease surveillance systems* Rev Sci Tech 2003, 22(2):689-96
    - http://www.oie.int/eng/publicat/RT/2202/28_SALMANang.pdf
- *Guidelines for the evaluation of public health surveillance systems*
    - http://www.cdc.gov/mmwr/preview/mmwrhtml/rr5013a1.htm

    - this approach is similar to that used by the OIE's *Performance, Vision and Strategy* tool for the evaluation of veterinary services, in which different elements of the system are scored against defined achievement criteria.

While an overall assessment of the many different elements of a surveillance system is essential to evaluating the system, the core purpose of the system is to generate surveillance data:

- evaluation of the quality of the data produced by a surveillance system is therefore the most important component of the overall evaluation.

The following sections deal with this aspect for the two broad purposes of surveillance.

Surveillance to demonstrate disease freedom or detect disease

The final conclusion when surveillance is undertaken to demonstrate freedom from disease, or for early detection of disease, is that:

- disease has been detected and is therefore known to be present, or
- that disease has not been detected, and is therefore believed not to be present.

This 'yes/no' result is modified by the awareness that it is possible to make mistakes:

- it is possible to falsely conclude that disease is present when it is not (a false alarm)
    - false alarms may cause concern and expense
    - nevertheless, they do not ultimately endanger the disease status of the population (no disease is present)
    - a good surveillance system should generate a false alarm from time to time
- it is possible to falsely conclude that disease is not present when it truly is (surveillance failure)
    - missing a genuine case of disease is a far more dangerous mistake.

A surveillance system can be thought of as a type of diagnostic test on the entire population:

- the population either has a disease or it doesn't, and the surveillance is used to make a decision
- the ability of a surveillance system to correctly identify a diseased population is the same as the ability of a diagnostic test to identify a diseased animal
    - it is measured quantitatively by the **sensitivity** of the surveillance system.

Sensitivity is the key measure of the quality of a surveillance system that aims to detect disease or demonstrate freedom from disease

- the evaluation of the quality of the surveillance system therefore depends on an estimation of the sensitivity of the surveillance system.

A number of key factors determine the sensitivity of a surveillance system:

- number of animals examined
    - the more examined, the higher the sensitivity
- quality of the test used on the animals
    - if the individual animal test is very sensitive, the overall surveillance system sensitivity is higher
- size of the population
    - this only plays a role in small populations where the number of animals sampled is large relative to the size of the population
- design prevalence
    - this determines our definition of a 'diseased population', and the standard our surveillance is trying to reach
    - it would be very difficult to detect disease in a large population if only one single animal were infected
    - however, if our definition of a 'diseased population' meant that at least 10% of animals were infected, it would be much easier to find at least one infected animal
    - the use of a low design prevalence makes the disease harder to find, and the sensitivity of the surveillance system lower

If the animals in the surveillance system are **representative** of the entire population (for instance, the sample had been drawn by random sampling), then:

- it is relatively easy to estimate the sensitivity of the surveillance system based on the above factors
- special software such as FreeCalc (included on the CD) is available to do these calculations.

However, if the surveillance system is complex, and the animals examined are not representative of the population, different techniques have to be used

- one approach is the use of scenario tree modelling, as described by Martin et al (2007)
    - P.A.J. Martin, A.R. Cameron and M. Greiner (2007) **Demonstrating freedom from disease using multiple complex data sources: 1: A new methodology based on scenario trees** *Preventive Veterinary Medicine* Volume 79, Issues 2-4 , 16 May 2007, Pages 71-97

- this technique captures all the factors that affect the probability that different animals will be infected, and that they will be detected by the surveillance system, in order to capture the biases in complex surveillance
- one advantage of this approach is that it explicitly and quantitatively captures the effects of targeted sampling in a surveillance system
- the methodology also allows sensitivity from different components of a surveillance system to be combined into a single overall estimate of sensitivity, and for the value of historical information from previous surveillance to be captured within sensitivity estimates
- unfortunately, the methodology requires some complex computer modelling techniques, but software is available to build and run these models (http://www.ausvet.com.au/freedom).

Surveillance to measure the level or distribution of disease

The key measure of a surveillance system to measure the level of disease is *prevalence*.

- various other measures may be used, such as incidence
- prevalence is most common, and will serve as an example for this discussion.

Assessing the quality of a measure of prevalence involves assessing the two types of error that can occur

1. systematic error
2. random error.

Systematic error is the error produced by some systematic problem in the surveillance system:

- if the same surveillance were conducted repeatedly on the same population many times, the error would always be present, and the result would be the same
- systematic error is measured by bias, and bias is defined as the difference between the true result, and the expected result of the surveillance system (expected result is the average of all results you would get if you repeated the same surveillance many times).
- for example, we might used abattoir surveillance to assess the prevalence of clinical paratuberculosis (Johne's disease) in cattle
    - this disease causes chronic diarrhoea and weight loss
    - therefore, affected animals are less likely to be sent to an abattoir than healthy animals
    - because of this, the prevalence of clinical cases of Johne's disease in a abattoir will always be lower than the prevalence in the general population
    - abattoir surveillance for Johne's disease is therefore biased.

Random error is due to the fact that the result of our surveillance can vary randomly, according to the simple chance choices of selecting this animal or the next animal

- with small sample sizes, the random error could be large
    - it is easy to get all healthy animals (estimated prevalence = 0%) from a population with 10% prevalence, if only 3 animals are chosen
- random error decreases with sample size
    - if 300 animals were chosen from a population with 10% prevalence, the number of infected is likely to be close to 30, even though it may be possible to get as low as 25 or up to 35
- the *precision* of an estimate describes how much random error there is
- when calculating the results, the size of the random error is measured by the *confidence intervals* around an estimate.

The two important measures of quality for surveillance to measure disease are therefore:

1. bias
2. precision.

Representative sampling

As described above, there are simple and well established approaches to calculating the precision of an estimate if the sample is representative of the population:

- the calculation is more complex if the structure of the surveillance is complex (for instance multistage sampling strategies), but can still be achieved.
- when the sample is representative, this means that the characteristics of the sample are the same as the characteristics of the population
    - by definition, there will be no bias.

Non-representative sampling

When surveillance is based on a non-representative sample, it is very likely that there will be bias:

- also, it is no longer possible to use the normal statistical approaches to calculating precision
- as with the previous case, complex methods exist to try to overcome these problems, but they are not simple to implement.

The most obvious way to estimate bias is to compare the real value in the population to that estimated by the surveillance:

- however, if we know the real value, we wouldn't need to do the surveillance

- one approach that has been used to overcome this problem is the use of 'capture / re-capture' methods
    - these techniques were originally designed for wildlife population estimation
    - for instance, to determine the size of a population of fish in a lake, some fish are caught from the lake, tagged, and then released
    - a short time later, some more fish are caught at the same lake
    - the proportion of fish that are caught the second time that were also caught the first time (and are therefore tagged) can be used to estimate the total number of fish in the lake
    - if the proportion of tagged fish in the second capture is large, that means that most of the fish that were caught the first time were caught the second time, implying that that is most of the fish in the entire lake
    - if the proportion is small, then there are many more fish in the lake than those caught the first time, so the population is large.
- when applied to surveillance, this technique involves capturing 'cases' using two or more different surveillance systems:
    - for instance, cases of disease that were identified in the main surveillance activity can be matched with cases that were detected by a special survey
    - these figures can be used to estimate the total number of cases of disease in the population, and, based on that, the bias present in the surveillance activity.
- for more information on capture-recapture techniques, see *Survey Toolbox for Livestock Diseases*.

How much surveillance is enough?

Surveillance is expensive:

- even passive surveillance requires an effected reporting and data management system to operate effectively, and this is expensive too.

However, surveillance is also very important:

- trading opportunities and the economic benefits may depend on it
- the success of a major disease control program may depend on it
- the welfare of the agricultural sector, through early detection of a disease incursion may depend on it.

Animal health decision makers therefore need to be able to determine the right balance:

- we need surveillance, but we want to make it as inexpensive as possible.

How much is enough, and how much is too much?

- this is a question that has been asked for many years, and is often very difficult to answer
- in some cases, such as demonstration of freedom for international trade, the purpose of surveillance means that there are clear benchmarks or standards that the surveillance has to achieve
- in others, the practical use of the surveillance and the decisions that are based on it, dictate the standards that are required
- however, in other cases, there are no clear standards.

Each of these three situations shall be considered in turn.

Existing standards

In the ideal situation, the quality standards for surveillance to demonstrate freedom from disease for trade purposes should be clearly agreed between trading partners, or be based on international standards:

- an example of such a standard is provided by the OIE Terrestrial Animal Code (Article 3.8.2.3, http://www.oie.int/eng/normes/mcode/en_chapitre_3.8.2.htm)
    - annual sample sizes shall be sufficient to provide 95% probability of detecting evidence of rinderpest if present at a prevalence of 1% of herds or other sampling units and 5% within herds or other sampling units.
    - this translates to achieving a surveillance sensitivity of 95%, with a herd-level design prevalence of 1% and animal level design prevalence within infected herds of 5%.
- using the quantitative analytical approaches referred to above, it is possible to use the design prevalence standards to calculate the actual sensitivity achieved by current surveillance system
    - if the result is greater than or equal to 95%, the surveillance is adequate to meet the standard
    - if it is less than 95%, it is not, and therefore has to be improved
- if the current surveillance exceeds the required standard there is a choice to be made:
    - decrease the level of surveillance so that it just meets the standard (therefore saving money), or
    - maintain a higher level to give a higher level of protection, and increase the confidence of trading partners
    - this is a political decision, and depends on available budget and the sensitivity of trading partners.

Implied standards

Consider the example of surveillance as part of a disease eradication program:

- a typical decision may be to decide when it is best to move from a vaccination policy, to decrease the level of disease to manageable levels, and switch to a test and slaughter policy to eliminate the last of the infected animals
- the point at which the policy changes should be based on economic modelling
    - the point at which the cost of test and slaughter becomes acceptable due to low prevalence, and the cost of continued vaccination (which may be unlikely to ever achieve final eradication) is too high, because it will continue for many years
- let us assume that the modelling has indicated that a prevalence of 2% is the appropriate level at which to change policy
- the purpose of surveillance is therefore to distinguish a population that has a prevalence greater than 2% from one that has a prevalence lower than 2%
    - any surveillance has some random error, so any estimate will have confidence intervals above and below it
    - the target prevalence (2%) and the size of the confidence intervals (precision of the estimate) represent the quality standards that can be used to evaluate the surveillance.
- deciding on the required precision is based on the implications of a bad decision:
    - if the prevalence is actually 5%, but the surveillance estimates it to be 2% so changes policy, what are the cost implications?
    - similarly, if the surveillance estimates the prevalence to be 2% but it is really 5%, how much more will this cost?
- using the same sort of economic modelling, it is possible to determine the acceptable limits for the estimate, where the cost of errors will be acceptable
    - these can then be used to determine the required precision, against which the existing surveillance can be judged.

No standards

The most difficult situation is when there are no external objective standards to assess how much surveillance is enough:

- for example, an early warning system performs a valuable function, in allowing rapid response to an incursion of disease:
    - if it works effectively, any disease outbreak will be quickly contained
    - if not, the outbreak may spread rapidly incurring major costs in terms of disease control and lost trade
- the principles are clear, but the practice is not:
    - any early warning system runs the risk of missing early cases
    - by spending more money on farmer and veterinary awareness, for instance, the sensitivity and timeliness of an early warning system can be improved, but it will still be neither complete nor perfect
- how much effort should be put into such a system?

Two main approaches have been used to address this problem:

1. continue with the current surveillance
    - this is pragmatic, but flawed
    - if there is an incursion of exotic disease that is not detected early enough, then more surveillance is required
    - if, however, after some time, there have been no incursions, or any incursions have been quickly detected, then the level of surveillance is reduced, step by step
    - this approach is almost guaranteed to generate periodic significant outbreaks, as the only way to know that you have reduced surveillance too much is when it fails.
2. an approach based on an insurance analogy
    - the amount that it is reasonable to spend on insurance (or surveillance) depends on:
        - the cost of the event you are insuring against, and
        - the probability that the event will occur
    - for example, if a significant outbreak of an exotic disease will cost $10,000,000, but would only occur every 50 years, then it is reasonable to spend up to 1/50 * 10,000,000 or $200,000 per year on surveillance to prevent a significant outbreak
    - these types of calculations are very uncertain because:
        - it is very difficult to predict the real cost of a future outbreak
        - it may be relatively small or enormous, depending on subtle random factors outside the control of the veterinary services.
        - the frequency of significant incursions is also very uncertain. This can be based on the historical pattern, but this is not necessarily an indication of the future risk, which is affected by changes in biosecurity, trading patterns, changes in disease strains and so on.
    - the above calculation assumes that the impact of the outbreak is completely avoided
    - however, in this example, early detection cannot avoid all the costs
        - for instance, even if the first affected herd is detected, there will still be a significant impact on trade, as trading partners immediately close their borders
        - it wil always take some time for these restrictions to be lifted.

Part 3: Appendices

Glossary of terms

(Courtesy of Dr Ian Gardner, University of California, Davis)

Accuracy	the degree to which a measurement, or an estimate based on measurements, represents the true value of the attribute that is being measured.
Agent	a factor such as a micro-organism or chemical substance whose presence or excessive presence is necessary for the occurrence of a disease.
Analytical study	a hypothesis testing method of investigating the association between a given disease, health state, or other outcome variable, and possible causative factors.
Benefit-Cost Ratio	the ratio of the net present values (usually monetary values) of measurable benefits to costs. Used to determine the economic feasibility or probability of success of a time-bounded program.
Bias	any effect at any stage of an investigation tending to produce results that depart systematically from the true values i.e. a systematic error.
Bias (Response bias)	a systematic error due to differences in characteristics between those who volunteer to participate in a study and those who do not.
Bias (Selection bias)	error due to systematic differences in characteristics between those animals or farms which are selected for study and those which are not.
Categorical Data	qualitative data which can be allocated to specific groups. May be nominal (ie. named) or ordinal (ie. ordered) or dichotomous (ie. presence/absence).
Chi-Square Test	a method of testing to determine whether two or more series of proportions or frequencies are significantly different from one another or whether a single series of proportions differs significantly from an expected distribution. Pearson's Chi-square is used for unmatched data and McNemar's Chi-square for matched data. See definition of association for further explanation.
Clustering	a closely grouped series of events or cases of a disease in relation to time or place or both. The term is normally used to describe aggregation of relatively uncommon events or diseases.

Confidence Limits	an interval whose end points can be calculated from observational data and has a specified probability of containing the parameter of interest.
Confounding	a situation in which the effects of two factors are not separated. The distortion of the apparent effect of an exposure or risk factor brought about by association with other factors that can influence the outcome.
Confounding Factor	a confounding factor or variable is one which is distributed non-randomly with respect to the independent (exposure) variable and is associated with the dependent (outcome) variable being studied. The association with the dependent variable is usually established from results of previous studies.
Contingency Table	a tabular cross-classification of data such that subcategories of one characteristic are indicated horizontally (in rows) and subcategories of another characteristic are indicated vertically (in columns), and the number of units in each cell is indicated. The simplest contingency table is the fourfold or 2 x 2 table, but a contingency table may include several dimensions of classification.
Continuous Data	quantitative data with a potentially infinite number of possible values along a continuum.
Cost Benefit Analysis	methods of identifying the losses and gains in monetary terms of the effects of a disease that are incurred by society as a whole.
Cross-Sectional Study	a study carried out on a representative sample of a population that examines the relationship between a disease or other health-related characteristic and other variables of interest as they exist in a defined population at one particular time. (syn: prevalence study)
Crude Rate	a rate which applies to a total population irrespective of the attributes of that population (cf. specific rate).
Data	facts of any kind. Data are plural, datum is singular.
Data Base	a systemized collection of information, commonly on electronic media about a specific subject such as animal disease.
Denominator	the population at risk in the calculation of a rate or ratio. See also Numerator
Dependent Variable	(syn:outcome/response variable) a variable or factor, the value of which depends on or is hypothesized to depend on the effect of other [causal]

	variable(s) in the study.
Disease	broadly speaking, any condition or abnormality of animal that interferes with its production or wellbeing. Subclinical disease is a disease that does not show any clinical signs, but which has an impact on the health or production of the animal.
Endemic Disease	the constant presence of a disease or infectious agent within a given geographic area or population group. It also implies a prevalence which is usual in the area or in the population.
Epidemic	the occurrence in a population or region of cases of disease clearly in excess of normal expectancy - this is frequently taken as more than two standard deviations greater than the mean occurrence.
Epidemic curve	a histogram in which the X-axis represents the time of occurrence of disease cases and the Y-axis represents the frequency of disease cases. It is a useful tool to determine the epidemiology of disease occurrence in an outbreak investigation.
Epidemic, Propagating	an outbreak or series of outbreaks resulting from animal to animal spread.
Epidemiology	the study of the distribution and determinants of health related states and events in populations. It is a term now in common usage for studies in animal populations although epizootiology is still occasionally used.
Epidemiology, Descriptive	study of the occurrence of disease or other health related characteristics in populations. Implies general observation rather than analysis.
Error, Sampling	after testing a sample from a large population, the mean or any other statistic calculated from the sample will have a different value from the true value if the whole population was measured. The difference between the value for the whole population and its estimate calculated from the sample is called the sampling error.
Error, Systematic	that due to factors other than chance, such as faulty measuring instruments.
False Negative	when the result of an individual test is negative but the disease or condition is present.
False Positive	when the result of an individual test is positive but the disease or condition is not present.

Frequency	a count, or number of occurrences, of an event in a specified population and time period.
Frequency Distribution	any arrangement of numerical data obtained by measuring a parameter in a population.
Histogram	frequency distribution plotted in the form of rectangles whose bases are equal to the class width and whose areas are proportional to the absolute or relative frequencies.
Hypotheses	a proposition that can be tested by facts that are known or can be obtained. The assertion that an association between two, or more variables or a difference between 2 or more groups, exists in the larger population of interest.
Incidence	the number of new cases of disease or other condition which occur in a specified population during a given period. Mathematically, 2 types of incidence rate can be distinguished. These are incidence density rates and cumulative incidence.
Incubation Period	the interval of time between invasion by an infectious agent or contact with a chemical and the appearance of symptoms of the disease or condition in question.
Independent Variable	the characteristic being observed or measured that is hypothesized to influence an event. An independent variable is not influenced by the event or manifestation but may cause it or contribute to its variation.
Index Case	the first diagnosed case of an outbreak in a farm or other defined group.
Infection	the presence of a disease agent that has active invaded or is multiplying in an animal. Infection does not always lead to disease. Where no multiplication takes place, an animal may be a carrier of the agent rather than infected by it.
Infectivity	the ability of an agent to enter, survive and multiply in the host. Epidemiologically, it is measured as the % of the individuals exposed to an agent who become infected.
Inference	the process of passing from observations to generalizations.
Latent Infection	persistence of an infectious agent within the host without symptoms of disease.

Linear Regression	statistical method used to study the relationship between independent and dependent variables when the dependent variable consists of continuous data.
Longitudinal Study	a study conducted over a defined period of time which may be either retrospective or prospective. See also Case Control and Cohort Study.
Mean - Arithmetic	a measure of central tendency computed by adding all the individual values together and dividing by the number in the group.
Median	the median is the middle value of a set of observations arranged in order of magnitude.
Mode	the mode is the most frequently occurring value in a set of observations. A given set of observations can have more than one mode. (see also Bimodal Distribution).
Monitoring	the performance and analysis of routine measurements aimed at the early detection of changes in the prevalence or incidence of disease, health, or alteration in a production parameter.
Multistage Sampling	a term applied to the selection of a sample in two or more stages. eg, selecting a sample of farms and then a sample of animals within those farms.
Nominal Data	a type of data in which there are limited categories but no order, such as breed and eye colour.
Normal	within the usual range of variation in a given population or population group; or frequently occurring in a given population or group.
Normal Distribution	a continuous symmetrical frequency distribution where both tails extend to infinity, the arithmetic mean, mode and median are identical. Graphically it is a bell shaped curve and its steepness or shape is completely determined by the mean and variance.
Notifiable disease	a disease for which the veterinary authorities have determined that notification is mandatory.
Null Hypothesis	the hypothesis that two variables have no association at all, or two or more population distributions do not differ from each other.
Numerator	the upper portion of a fraction used to calculate a rate or ratio.

Observational Study	an epidemiological study where nature is allowed to take its course while changes or differences in one characteristic are studied in relation to changes or differences in other(s) without intervention of the investigator (e.g. descriptive, cross-sectional case-control, cohort).
Occurrence	a statement indicating the presence of disease without signifying the frequency. This definition describes the use of the word in international animal disease reports.
Ordinal data	a type of data in which there are limited categories with an inherent ranking from lowest to highest (such as severity of disease).
Outbreak	the occurrence of disease in a farm or any other identifiable group of animals. For practical purposes, the term is synonymous with epidemic.
Outliers	observations differing so widely from the rest of the data as to lead one to suspect that a gross error in recording may have been committed, or suggesting that these values came from a different population.
Pandemic	an epidemic occurring over a very wide area, involving many countries and usually affecting a large proportion of the population.
Parameter	a summary descriptive characteristic of a population (cf statistic which is a sample-based measure).
Pathogen	an agent capable of causing disease
Pathogenicity	the ability of an organism to produce disease. Epidemiologically, it is measured as the % of infected individuals who develop clinical disease.
Power	probability of finding a difference between two or more groups given that a difference exists. Power = 1-Beta = 1-Probability of a type II error.
Precision	the quality of being sharply defined or stated. Refers to the ability of a test or measuring device to give consistent results when applied repeatedly. Sometimes also called repeatability.
Predictive Value	in screening or diagnostic tests, the predictive value of a positive test is the proportion of test positive animals that have the disease. The predictive value of a negative test is the probability that an animal with a negative test does not have the disease. The predictive value of a test is determined by the sensitivity and specificity of the test, and by the prevalence of the condition at the time the test is used.

Prevalence — the proportion of cases of a disease or other condition present in a population without any distinction between old and new cases. When used without qualification the term usually refers to the number of cases as a proportion of the population at risk at a specified point in time (point prevalence).

$$\text{Prevalence} = \frac{\text{No. cases at specific point in time}}{\text{Population at risk at same point in time}}$$

Prevalence study — see cross-sectional study

Primary Case — the individual that introduces disease into a farm, pond, or other group under study. Not necessarily the first diagnosed case in that group. See index case.

Proportion — a fraction where the numerator is a subset of the denominator.

Prospective Study — see Cohort Study.

Qualitative data — that which possess specific qualities such as breed, gender, or colour. See nominal data.

Random — governed by chance.

Random Sample — a sample of a population assembled so that each member of the population has a known and non-zero opportunity to be selected.

Random Sampling — procedure for selecting individuals from a population so that each has an equal chance of being selected in the sample.

Randomization — allocation of individuals to groups by chance. Within the limits of chance variation, randomization should make control and experimental groups similar at the start of an investigation and ensure that personal judgement and prejudices of the investigator do not influence allocation. Note that random allocation follows a predetermined plan often devised with the aid of a table of random numbers or by an electronic random number generator.

Rate — an expression of the change in one quantity per unit time. It is a ratio whose essential characteristic is that time is an element of the denominator and in which there is a distinct relationship between

numerator and denominator. See also ratio and proportion.

Ratio — the expression of the relationship between a numerator and denominator where the two are separate and distinct quantities, i.e the numerator is not included in the denominator.

Relative Risk — the ratio of the disease incidence in individuals exposed to a hypothesized factor to the incidence in individuals not exposed; a measure of association commonly used in cohort studies. See also odds ratio.

	Diseased	Not diseased
Exposed	a	b
Unexposed	c	d

The Relative Risk is [a/(a+b)] ¸ [c/(c+d)]

Repeatability — the ability of a test to give consistent results in repeated tests. See precision.

Response Rate — the number of completed or returned survey instruments (questionnaires. interview etc.) divided by the total number of individuals selected for study.

Retrospective Study — a study that collects and utilizes historical data. A case-control study is retrospective because it looks back from the point of known effects to determine causative factors.

Risk factor — a factor which is associated with an increase in the risk of disease in animals. When this factor is present, one would expect to see a higher rate of disease than when the factor is not present. Risk factors may or may not be causes of disease.

Robust — a statistical test is described as robust if the inferences hold true even when assumptions inherent in the tests are violated.

Sampling — the process of selecting a number of representative subjects from all the subjects in a particular group. Conclusions based on sample results may be attributed only to the population sampled. See also random sample and selection bias.

Screening — implies subjecting a population or sample of a population to a diagnostic test or procedure, with the objective of detecting disease. Tests used for

	this purpose are usually cheap, easily performed, sensitive but often not very specific.
Sensitivity	is the proportion of truly diseased animals in the screened population which are identified as diseased by the test. It is a measure of the probability that a diseased individual will be correctly identified by the test.
Sentinel Farms	farms that are reasonably representative of the population as a whole and which are tested at regular intervals for infectious disease to determine whether and to what extent the diseases are occurring in the population.
Seroepidemiology	epidemiological studies based on an examination of sera taken from the population or a sample of the population.
Significance, Level of	also known as alpha (a) or type I error rate. The probability of saying a difference exists when none does.
Spatial distribution	the relationship of disease events to location of individual animals or clusters of animals.
Specific Rate	expresses the frequency of a characteristic per unit size of a specific population.
Specificity	is the proportion of truly non-diseased animals correctly identified by the test. Like sensitivity, specificity is a conditional probability.
Sporadic	a disease occurring irregularly and generally infrequently and without any apparent underlying pattern.
Standard Deviation	a measure of dispersion or variation. Equal to the positive square root of the variance. The mean indicates where the values for a group are centred. The standard deviation is a measure of how widely values are dispersed around the mean in the population.
Standard Error	measure of the variability of a sample statistic that specifically relates an observed mean to the true mean of the population.
Statistic	a summary value calculated from a sample of observations usually to estimate a population parameter.
Statistical Significance	statistical methods allow an estimate to be made of the probability of the observed degree of association between independent and dependent variables being exceeded under a null hypothesis. From this estimate the

	statistical "significance" of a result can be stated. Usually the level of statistical significance is stated by the "P" value or probability value. See also Significance, Level of.
Statistics	the science and art of dealing with variation in data through collection, classification, and appropriate analysis.
Stratified Sample	involves dividing the population into distinct subgroups according to some important characteristic, e.g. pond size, and selecting a random sample out of each subgroup.
Surveillance	a system or measurement technique to gain knowledge about a population by collection, analysis, and interpretation of data with a view to the early detection of cases of disease or changes in the health status of the population. The goal of surveillance is directed action in the treatment or prevention of the condition.
Survey	an investigation in which information is systematically collected.
Systematic Sample	the procedure of selecting according to some simple systematic rule, such as every 5th fish in the tank as they are transferred to another tank.
Temporal Distribution	the relationship of disease events to time.
Trend	a long-time movement in an ordered series (e.g. a time series). An essential feature is that the movement, whilst possibly irregular in the short term, shows movement consistently in the same direction over a long term.
Type I Error	an error which occurs when using data from a sample that demonstrates a statistically significant association when no such association is present in the population. Equals the level of significance or alpha.
Type II Error	an error that occurs from failure to demonstrate a statistically significant association when one exists in a population. Equals Beta. The power of a study equals 1-Beta.
Validity	the extent to which a study or test measures what it sets out to measure.
Variable	see Dependent variable, Independent variable.
Variance	the variance of a set of observations is the sum of squares of the deviation of each observation from the arithmetic mean of the

	observations, divided by one less than the number of observations.
Virulence	the degree of pathogenicity and indicates the potential severity of the disease produced by an agent in a given host. Epidemiologically, it is measured as the % of individuals with disease who become seriously ill or die. Sometimes, the case-fatality rate is considered an indicator for the virulence of disease.

Resources and References

This is a list of resources that may be of value to training course participants. Those that are in the public domain and available in electronic format are included on the accompanying CD. Those that are copyright and print only are referenced.

Surveillance specific resources

Cameron, A.R. (1999) Survey toolbox for livestock diseases: a practical manual and software package for active surveillance in developing countries. ACIAR, Canberra, Australia

OIE (2006) Terrestrial Animal Health Code (Web Version), Appendix 3.8.1: General Guidelines for Animal Health Surveillance http://www.oie.int/eng/normes/mcode/en_chapitre_3.8.1.htm

Jeffrey C. Mariner and Roger Paskin (2000) FAO Animal Health Manual 10: *Manual on Participatory Epidemiology - Method for the Collection of Action-Oriented Epidemiological Intelligence*, FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, Rome 2000 http://www.fao.org/docrep/003/X8833E/x8833e00.HTM

Cameron, AR (2004) Principles for the Design and Conduct of Surveys to show Presence or Absence of Infectious Disease in Aquatic Animals, National Aquatic Animal Health Technical Working Group - Policy Document.

General resources

Proceedings of the International Symposium for Veterinary Epidemiology and Economics (ISVEE) (1976 - 2006) http://www.sciquest.org.nz/default.asp?pageid=97

Thrusfield M, *Veterinary Epidemiology*, 3rd ed. Blackwell Publishing Professional, Ames, Iowa, USA, 2005

Cameron, A.R., Sergeant, E.S. and Baldock, F.C., AusVet Series in Epidemiological Skills for Animal Health Professionals, Volume 1: *Data Management for Animal Health*. AusVet Animal Health Services Pty Ltd, Brisbane, Australia: 2005

Sergeant, E.S., Cameron, A.R. and Baldock, F.C., AusVet Series in Epidemiological Skills for Animal Health Professionals, Volume 2: *Epidemiological Problem Solving*. AusVet Animal Health Services Pty Ltd, Brisbane, Australia: 2005

FAO Multimedia Program on Good Emergency Management Practice http://www.fao.org/AG/AGA/AGAH/EMPRES/e_gemp.htm

F. Goutard, J. Thonnat, B. Toma, B. Dufour, J. Queste, N. Chansiripornchai, F. Roger. *RANEMA: a computer assisted learning tool for basic epidemiology.* , as described in Proceedings of The 12th International Conference of the Association of Institutions for Tropical Veterinary Medicine, Montpellier, France 20-22 August 2007

Toma,B., Dufour,B., Sanaa,M., Benet,J.-J., Ellis,P., Moutou,F. and Louza,A. (1999) Applied veterinary epidemiology and the control of disease in populations. Maisons-Alfort, France: AEEMA, 536pp.

Model Documents

These documents will be included on the CD to act as models to assist future users of the manual in structuring appropriate reports. The models will include edited versions of the project outputs of the participants.

- Report of participants' surveillance project
- Example surveillance reports.

Formulae

Combining multiple tests

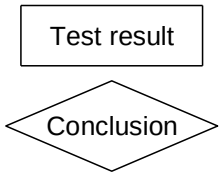
When combining tests, the combined test sensitivity and specificity depends on:

- The sensitivity and specificity of each of the component tests
- The interpretation of the test combination
- Any interactions between the tests

The combined values can be easily calculated using the following formulae if the individual are considered independent. In practice, this means that the tests are based on different biological processes. For instance, histology, serology and culture are all independent. However two tests that both aim to detect antibodies, such as an ELISA and an AGID are not independent. They should either not be used in combination, or if they are, more complicated analysis techniques are required to take account of the lack of independence.

The following diagrams are useful for deriving the formulae for calculating sensitivity and specificity when combining tests.

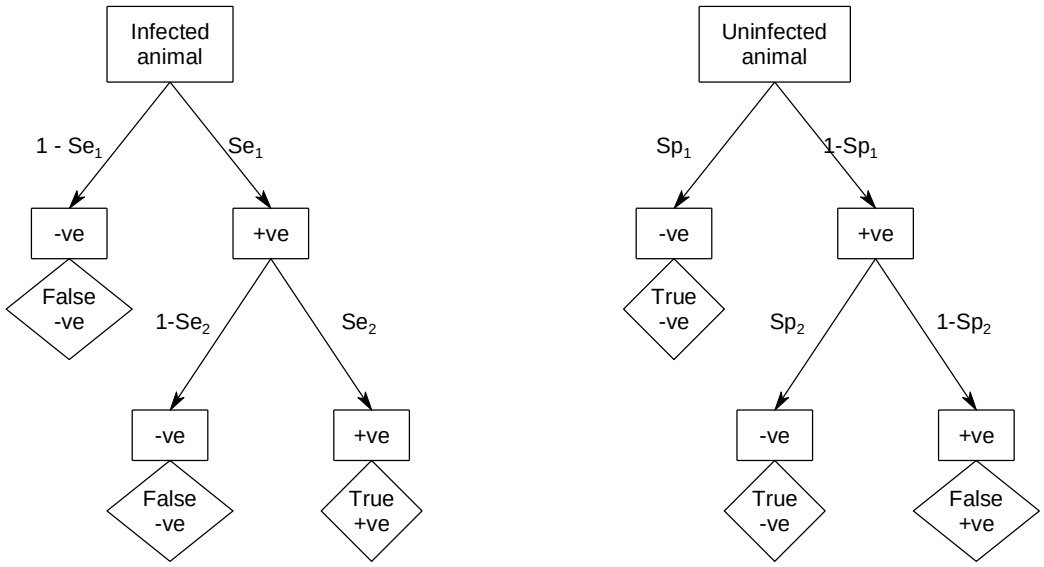
In these diagrams the following symbols are used:



Maximising specificity

Combining tests to increase the specificity is sometimes referred to as serial testing. In order for an animal to be considered positive, it must give a positive result to both the first and the second test. Animals are only retested if the first test gives a positive result.

This is illustrated below:



In the case of truly positive animals (the diagram on the left), the combined sensitivity of the two tests can be calculated by multiplying the probabilities down the branches of the tree that give a positive result.

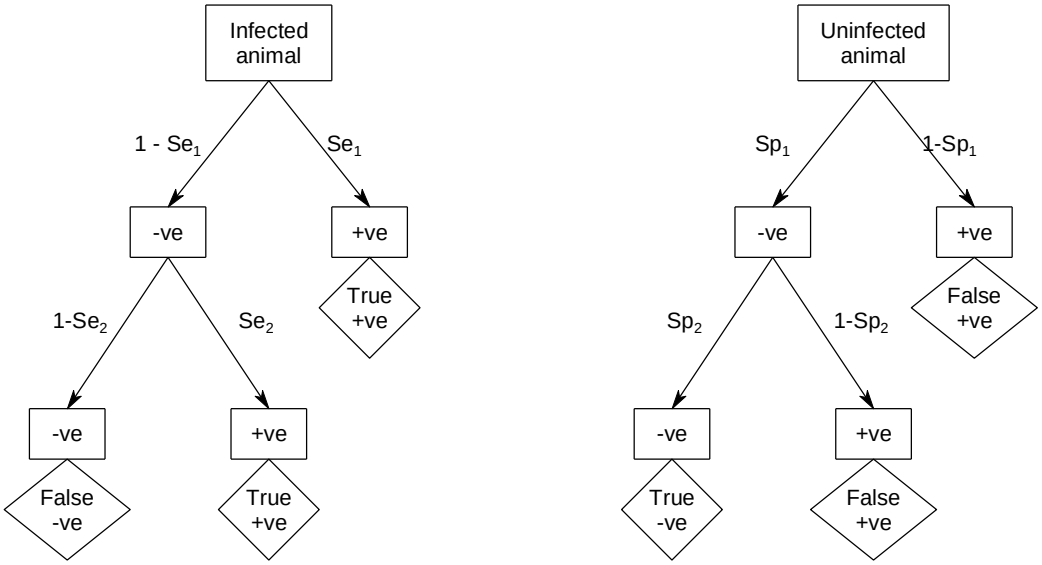
$$Se_{Combined} = Se_1 * Se_2$$

For negative animals, the same approach is used, multiplying all the branches that give a negative result. However, in this case, there are two ways to give a negative result (first test negative, or first test positive and second test negative), so the probability of each is added together:

$$Sp_{Combined} = Sp_1 + [(1-Sp_1) * Sp_2]$$

Maximising sensitivity

The alternative approach to interpreting multiple tests is to only consider that an animal is negative if it tests negative to both tests, as illustrated in the diagrams below.



In the case of truly positive animals (the diagram on the left), the combined sensitivity of the two tests is

$$Sp_{Combined} = Se_1 + [(1-Se_1) * Se_2]$$

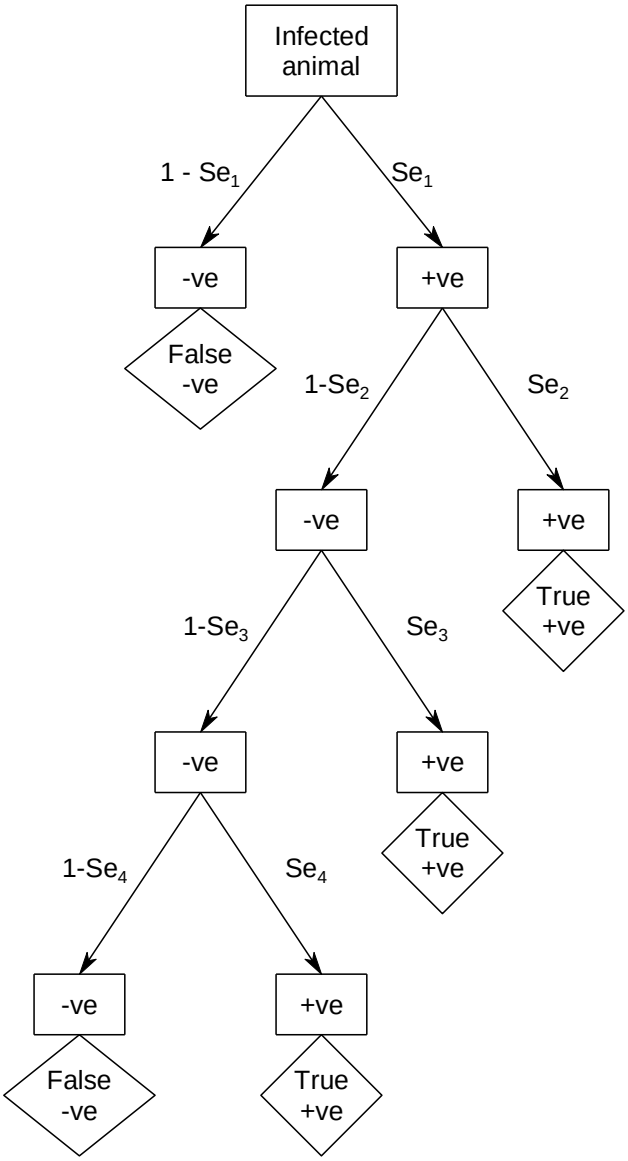
For negative animals:

$$Se_{Combined} = Sp_1 * Sp_2$$

Using these diagrams it is easy to extend this approach to three or more tests, and to the more complex situation where different interpretations are used at different stages of the testing.

For instance, a (real world) testing scheme for tuberculosis uses an initial screening test (the comparative skin test) followed by a combination of three confirmatory tests (culture, PCR and histology). If the animal is negative to the screening test, it is considered negative. However if it is positive to any of the three confirmatory tests, it is

considered positive. The sensitivity of this test combination would be described by the diagram below:



The sensitivity could therefore be calculated based on all the pathways that give a positive result:

$$Se_{Combined} = Se_1 * Se_2 + [Se_1 * (1- Se_2) * Se_3] + [Se_1 * (1- Se_2) * (1- Se_3) * Se_4]$$

The specificity can be calculated in a similar way.

Calculating true prevalence

The formula for calculating the true prevalence (TP) based on the apparent prevalence (AP) obtained for a study using a test with a given sensitivity (Se) and specificity (Sp) is:

$$TP = \frac{AP + Sp - 1}{Se + Sp - 1}$$