Manual of Basic Animal Disease Surveillance

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AFRICAN UNION
**INTERAFRICAN BUREAU
FOR ANIMAL RESOURCES**

MANUAL OF BASIC ANIMAL DISEASE SURVEILLANCE

An AU-IBAR Publication

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FOREWORD

The African Union - Interafrican Bureau for Animal Resources (AU-IBAR), in pursuit of its mandate, has for a long time invested in capacity building to equip nationals from African countries with the skills required to support the animal resources sector. Special emphasis has been put on animal health for a long time to address the huge challenge of animal diseases and their impacts on human wellbeing. Inspite of the many memorable achievements realized in this endeavour, including but not limited to the recent eradication of rinderpest, a lot of work remains to be done to minimize the negative impacts of animal diseases and zoonoses. Achieving this objective requires continuos investment in physical infrastructure, coordination mechanisms, institutional systems and human capital to sustain pressure on disease prevention and control.

The war on diseases can only be won if we are able to detect them early and control them before they spread far or become entrenched. Achieving this requires skills in surveillance techniques and the ability to take action on surveillance findings. During recent training on risk-based surveillance of veterinary epidemiologists from 43 African countries, it was evident that more skills were required to realize the full benefits of disease surveillance interventions. Additionally, a need was found to invest in an effort to standardize understanding and practice of surveillance to ease information sharing and data analysis.

This manual has been developed with these considerations in mind and is expected to serve as a basic tool for use by persons interested in disease surveillance. It is my sincere believe that it will be useful to epidemiologists, students and veterinary practitioners in Africa.

Thank you.

Professor Ahmed El-Sawalhy
Director AU-IBAR

ACKNOWLEDGEMENTS

INTRODUCTION

Every country in the world has some sort of animal disease surveillance system. Surveillance is needed to understand the health status of the animals in the country, so that problems can be identified and actions can be taken. However, different countries have very different surveillance needs and surveillance capabilities: a wealthy country with few diseases that depends on exports of animals and animal products will have sophisticated surveillance systems to protect trade. A poor country with uncontrolled land borders with multiple other countries that have regular outbreaks of epidemic diseases will be unable to maintain sophisticated surveillance systems and will aim primarily at minimising the impact of major animal diseases.

Since the 1990s, there have been significant developments in approaches to animal disease surveillance, due to the development of comprehensive population databases, the availability of better data management and analysis tools, new statistical techniques and an improving understanding of concepts of risk in surveillance. The result has been that veterinary authorities planning new surveillance activities or aiming to improve existing surveillance have a wide range of options open to them. They are able to select the specific surveillance tools best suited for a particular task. The available surveillance tools vary greatly in terms of cost, complexity, purpose and effectiveness.

This increased choice is a good thing. The more options there are for gathering information about a particular disease, the more likely it is that veterinary authorities will be able to find at least one of those options which will meet a country's specific requirements in terms of information needs and resource constraints.

However, with increased choice comes increased complexity. Surveillance has become a technically complex area and there is a need for expertise to evaluate the advantages and disadvantages of different surveillance options, and to decide on the most appropriate approach for any given situation. Unfortunately, in many countries, this expertise is not available, making it difficult to understand what tools are available and to decide on the best tool to use in a particular situation.

This manual aims to assist veterinary authorities in developing countries in deciding on the best approach to animal disease surveillance, depending on their own needs and capabilities. Part one establishes a framework for deciding on the best approach to surveillance. This involves:
- Identifying the various purposes of surveillance, and the information requirements to meet each of these purposes;
- Identifying the surveillance tools available, their characteristics and the information that they are able to generate; and
- Matching the tool to the purpose of surveillance.
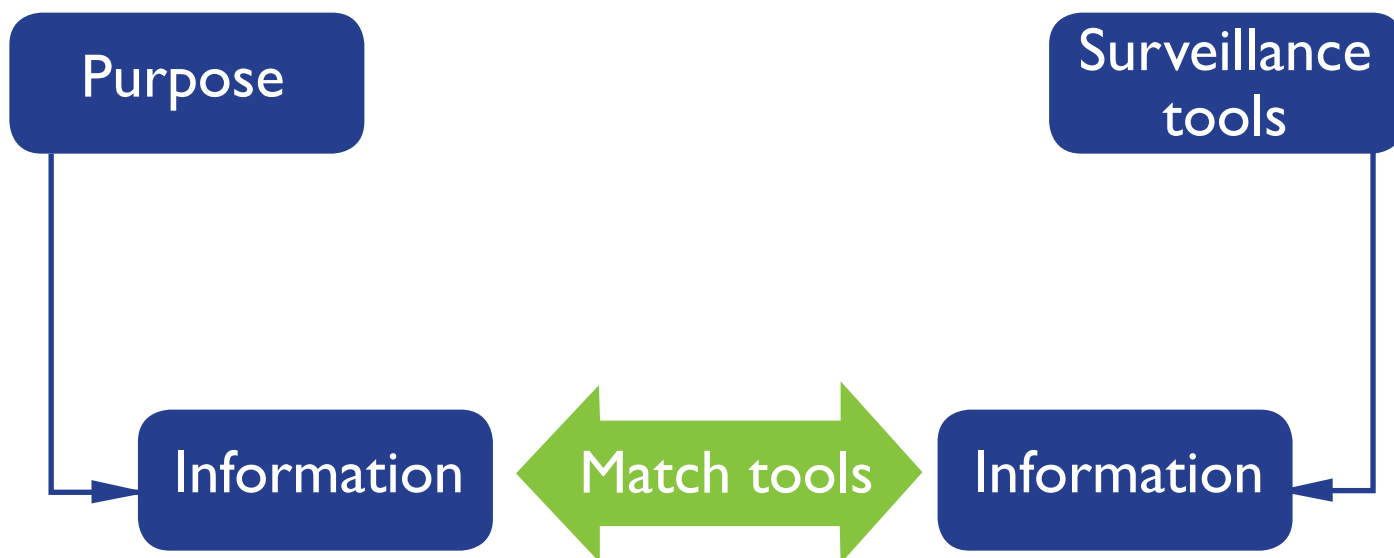
Part two examines the strengths and weaknesses of key surveillance tools and provides a step by step guide to effectively implement basic animal disease surveillance.

While this manual is targeted specifically at developing countries with significant resource constraints, the principles discussed may be of value to more developed countries trying to prioritise different surveillance activities. The framework of surveillance needs and surveillance tools laid out in this manual should help veterinary authorities from countries at different levels of development make better decisions about animal disease surveillance.

PART 1:
BASIC REQUIREMENTS

PURPOSES OF SURVEILLANCE

Before considering how to best implement animal disease surveillance, we should first have a clear understanding of why we need to do surveillance. There is a large number of reasons why veterinary authorities undertake surveillance activities, but these can be summarised into four general purposes:
- Demonstrating freedom from disease
- Early detection of disease
- Measuring the level of disease
- Finding cases of disease

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Absent ──────► Early detection
        └─────► Demonstrate freedom

Present ─────► Case finding
         └────► Measure level of disease
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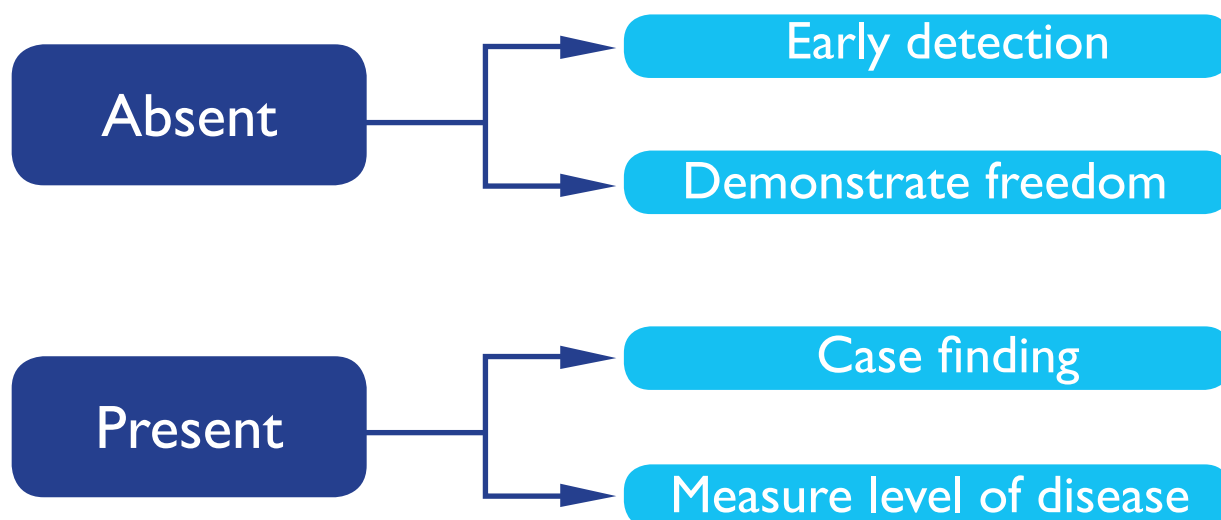
These four general purposes are discussed and explained in more detail below. It is easier to understand the difference between these purposes if they are divided into two groups: surveillance for diseases that are currently or usually not present, and surveillance for diseases that are present.

Note that throughout this discussion, the term 'disease' is used. Strictly speaking, disease refers to the clinical manifestations of some infection, infestation or health condition. Surveillance can be conducted for the underlying condition or infection (and so can include surveillance for subclinically affected animals). In this manual, 'disease' will also be used to imply underlying infections or conditions unless otherwise stated.

Diseases that are not currently or normally present

These diseases include:
- Exotic diseases (known diseases that are not present in the country, but do exist in other countries);
- Emerging diseases (recently identified diseases that are changing in their importance due to increased host range, pathogenicity or spread);
- New diseases (diseases which have not previously been recognised);
- Epidemic diseases (diseases which may be present in the country but appear in any one location sporadically in the form of an outbreak, and then do not occur for a certain period)

The two purposes for surveillance of diseases that are absent are to demonstrate freedom, and early detection of disease.

Demonstrating freedom from disease

When disease is not present in a country (or a zone or compartment within a country) there may be a number of benefits, including the ability to export animals or to cease disease control measures (such as a vaccination program). However, in order to get these benefits, the veterinary authorities must first be confident that the disease is truly absent.

Demonstrating freedom from disease is difficult. To prove that a disease is present in the country, one only needs to find a single infected animal. However, examining hundreds or thousands of animals and finding that they are all uninfected still does not prove that the disease is absent, as there is always a chance that there

remains a small number of infected animals that have not yet been examined. For this reason, demonstration of freedom from disease normally uses a probabilistic approach; based on the surveillance evidence, we estimate how likely it is that the country is free from infection.

The reasons for demonstrating freedom from disease include:

Trade access
- If the animals in an exporting country have been demonstrated to be free from disease, it is safe to export those animals to another country.

Trade barrier
- If an importing country has demonstrated that it is free from infection, that country can prevent the import of animals from an infected country (subject to a risk analysis).

Stopping control or eradication measures
- If the disease has been the subject of an eradication campaign, a range of control and eradication measures may have been used, including vaccination, test and slaughter, movement restrictions, farm-level biosecurity and so on. These measures may be very expensive, but if they are stopped before the disease is eradicated, there is a risk that the disease will again spread through the population. In order to decide that it is safe to stop disease control measures, the veterinary authorities must first be confident that the disease has been truly eradicated.

Public health
- For zoonotic diseases, public health measures may be in place to control the risk of spread of the disease to the human population. These might include specific testing at meat inspection or prophylactic measures in the human population. If the disease is shown to be absent, these measures can be stopped.

Political
- The ability to successfully eradicate an animal disease may be a matter of national pride. Recognition of the success of such a program may be important for political reasons.

Early detection of disease
Early recognition of a disease incursion may be important for:

Early response
- The cost and effectiveness of eradication or control of a new disease outbreak is normally directly related to the delay in detection. Being able to detect new disease incursions as quickly as possible is important for effective control.

Prevention of spread
- For an exporting country, if there is an undetected outbreak of an exotic disease, this may then spread to a third country through animal exports. Most importing countries will demand that exporting countries have a capacity for early detection to prevent the spread of disease.

Diseases that are present
These diseases include recognised endemic diseases. The two reasons for surveillance of diseases that are present are to measure the disease, or to find cases of the disease.

Measuring the level of disease
The ability to measure the level of disease is useful for a variety of reasons. The most common measures of disease used include prevalence and incidence, but a variety of other epidemiological measures are also available (for example, mortality rates).

Single measures of the level of disease
- A single measure provides an indication of the level of the disease in a population at one point in time.

This may be useful for:

Prioritisation of disease
• When combined with data on the economic impact of disease, single measures of different diseases can be used to determine those with the greatest impact, and help the veterinary services prioritise disease control activities

Risk analysis
• An important input into risk analysis is the prevalence of the disease in the population of origin. Surveillance may be used to provide this information.

Multiple measures of disease for comparison
• *Spatial distribution of disease*
  ◊ Understanding spatial risk factors
    - Measuring the level of disease in different geographical areas (for instance provinces or districts) may provide clues about factors that influence the disease. For instance, the observation that avian influenza outbreaks in domestic poultry are sometimes more common in or around wetlands that attract wild birds indicates that wild birds may be a source of spreading the disease.

  ◊ Establishing disease free zones
    - Disease-free zones may be used to facilitate trade or for progressive disease control and eradication. By studying the spatial variation in the distribution of the disease, it is possible to identify areas where the disease is absent or of which the level is low, and which may therefore be used as the basis for a zoning system.

• *Temporal distribution*
  ◊ Monitoring control programs
    - Disease control programs (such as vaccination programs) are often expensive and last for many years. It is important that any problems with these programs can be quickly detected and corrected, to ensure that money spent on the program is not wasted. Measuring program progress (for example, by measuring the level of disease or of vaccine-induced antibodies) at regular intervals should be part of every control program.

  ◊ Early detection of changes in endemic disease
    - Diseases can change, either because of changes in the agent, the host or the environment. Just as it is important to be able to detect new diseases, it is also important to be able to detect and respond to changes in the behaviour of existing diseases so that actions can be taken.

• *Other factors*
  ◊ The previous paragraphs have discussed measuring differences in the level of disease between locations or over time, in order to better understand the factors associated with the disease and respond to changes. Similarly, variation in the level of disease with respect to other important factors (such as sex, age or production system) can be used to provide clues to improved control or detect changes in the behaviour of the disease.

Finding cases of disease
In some situations, surveillance aims to detect individual cases of disease, or individual outbreaks of disease. This is most common with surveillance as part of a disease control program. For instance, the main aim of surveillance for bovine spongiform encephalopathy (BSE) at abattoirs is to identify infected individuals and remove them from the food chain. The data gathered is also used to measure the level of disease (prevalence of BSE), but the prime purpose is case finding.

Surveillance as part of control programs for diseases such as contagious bovine pleuro-pneumonia (CBPP) or tuberculosis (Tb) aims to find either infected herds or infected animals within herds, and remove them from the population.

Conclusion

This chapter has presented four main purposes for surveillance, depending on whether disease is normally present or absent from the country. It is possible to identify other purposes for surveillance but most can be classified according to the four purposes presented here.

For any given country, the purposes of surveillance will vary according to the country's needs and situation. The next chapter examines the different surveillance requirements of different countries.

SURVEILLANCE REQUIREMENTS

The previous chapter discussed the four general possible purposes of surveillance. However surveillance needs and priorities vary between different countries, as well as between different levels. For instance, the animal health information needs of a farmer or district veterinary officer may be very different to those working at the national level or in an international organisation. This chapter outlines the minimum surveillance requirements at the national level for most veterinary authorities, as well as possible additional information needs related to different activities.

Who is surveillance for?

In many developing countries, surveillance systems have been implemented and developed with support from internationally-funded projects, and there is ongoing encouragement and support for effective surveillance from regional and international animal health organisations such as the World Organisation for Animal Health (OIE) or the Food and Agriculture Organization of the United Nations (FAO). These organisations place emphasis on international reporting on animal health status. As a result, some national veterinary services give the impression that the main purpose of surveillance is to meet the international reporting requirements of these organisations.

The main role of international organisations such as the OIE is not simply to receive surveillance reports from member countries, but to share this information with other countries. In this way, when there is a new outbreak of a disease in one country, those countries that are at risk of disease spread (for instance, countries importing animals from the affected country, or closely neighbouring countries) are able to take appropriate steps to limit the risk. The final users of the surveillance information are the countries themselves – the international organisations simply provide a means to communicate this information between countries.

As national veterinary services are the organisations responsible for implementing disease control measures (whether the threat is internal or international), the main purpose of surveillance is to provide information to the national veterinary services to enable them to make appropriate, well-informed decisions about disease control. When designing a surveillance system, priority should always be given to national-level information needs before those of international organisations.

For instance, a country with a very small surveillance budget has a major problem with intestinal parasites. While the number of animals dying is limited, parasites in this country cause massive loss of productivity. Based on a prioritisation exercise, the veterinary services decide to launch a program to minimise the impact of intestinal parasites through a comprehensive extension program, improved management and the establishment of strategically timed anthelmintic treatments. Due to the limited budget, this control program represents a significant investment by the veterinary authorities. It is therefore very important to ensure that the program is having the desired effect and that funds are not being wasted. The veterinary services therefore implement a surveillance program to monitor parasite levels over time, in the hope that they will decrease as the program progresses. This is an appropriate use of the surveillance budget.

At the same time, the process of global eradication of rinderpest has come to a close. FAO stresses the importance of ensuring that every country on the globe undertakes adequate surveillance to demonstrate freedom from rinderpest.

The veterinary services therefore have two competing demands on their limited surveillance budget. Should they focus on surveillance to support the control program for internal parasites (a disease which has no relevance to OIE or FAO), or should they redirect funds to the globally important issue of rinderpest?

While this may be an extreme example, this is the type of prioritisation questions with which veterinary services are constantly faced. Both surveillance activities are important, but they are important to different groups. Parasite surveillance helps the rural poor of the country, while rinderpest surveillance provides benefits to the global animal health community (but virtually no direct benefits to the rural poor). In practice, it is rarely a decision between one activity or the other – both are important. However, with limited funds, it would be appropriate for the veterinary services to prioritise surveillance that has a direct impact on the wellbeing of farmers. Instead of devoting scarce resources to rinderpest surveillance, it may be more

appropriate to investigate alternative approaches to rinderpest surveillance that may be able to generate a similar level of confidence in freedom from infection, while costing much less than an expensive serosurvey. Fortunately, for key surveillance activities, the needs of the national veterinary services and those of the international organisations are often very similar.

Required national surveillance capabilities

The required surveillance capabilities of countries will vary according to their circumstances. While some capabilities are required of every country, the need to undertake some types of surveillance will depend on national priorities, including whether specific disease control or eradication programs are in place, and whether the country needs to support export markets or is an importing country.

General requirements of every country

The minimum surveillance capabilities that every country should have are relatively simple. The veterinary services should be able to:
- Describe what important diseases are present, and
- Detect the occurrence of important new, emerging or exotic diseases.

A country that is not capable of these two surveillance functions could be said to have a non-functioning veterinary service.

Describe the current disease situation

Knowing what major diseases are present is important to ensure that the veterinary services are capable of responding to disease problems and providing support for its livestock producers. Even if the resources to respond to problems are limited and it is not possible for the veterinary services to mount a major disease control program, information on which diseases are the major causes of animal health problems will be required to seek assistance from bilateral or international aid organisations.

Note that, in its most basic form, this list simply identifies those important diseases that are present, and does not necessarily rank or prioritise the diseases. This would require an unbiased measure of the level of each disease (and an analysis of the social, economic, environmental or public health impact).

Detect new, emerging and exotic diseases

Similarly, every country has a responsibility to detect the occurrence of new diseases. For incursions of exotic diseases, early detection is essential if the health of livestock populations is to be protected.

There has been an increased awareness of the threat posed by new and emerging diseases over the last few decades, due to the apparently increasing rate of emergence of new diseases in animal populations and the fact that a number of these diseases have been zoonotic (such as BSE, highly pathogenic avian influenza (H5N1), Nipah virus, SARS etc). Globalisation and the rapid movement of people and goods (including animals and animal products) mean that new diseases emerging in one part of the world pose a significant threat to all other countries. Early detection is essential to effective control, and the organisation responsible for early detection is the veterinary authority of the country in which the disease first appears.

Early detection of new and emerging diseases is therefore an important responsibility for national veterinary services, not only to protect their own animal industries (as with detection of recognised exotic diseases), but also to help protect the global community (as nobody else is able to perform that task).

These two capabilities (describe the current disease situation and early detection of incursions) are fundamental to any veterinary service. However, further surveillance requirements will depend on the country's situation. The following sections provide examples of surveillance requirements in different circumstances, but this list is not exhaustive.

Endemic disease control programs

A country that is implementing a control program for endemic or epidemic disease needs more information from surveillance than can be gathered from the basic two requirements listed above. In particular, surveillance

may be required for:
- Priority setting
- Monitoring program effectiveness
- Case finding

Priority setting
It is illogical to establish a disease control program for an unimportant disease, while more important diseases remain uncontrolled. Planning a disease control program therefore first involves identification of the most important diseases. Priority setting generally involves a number of steps:
- Surveillance to measure the level of disease. Disease occurrence is normally measured using prevalence or incidence.
- Estimating the impact of the disease. First, the impact of a single case of disease is estimated (for instance, does it kill the animal, causing major loss, or does it just cause temporary loss of production followed by full recovery). Impact may be evaluated in economic terms (financial loss due to the disease) or more often relative to a number of other measures (for example, social, environmental or public health impact).
- Ranking of diseases. Those diseases with the highest impact are identified and ranked.
- Feasibility and cost-effectiveness of control. High-impact diseases may be very difficult and expensive to control, while an important disease, be it with slightly lower impact, may be able to be controlled at a much lower cost. A cost-benefit analysis is required to confirm that a control program is justified and to identify those programs which will produce the greatest overall benefit.

As noted, the first step in priority setting for disease control programs is surveillance. Unlike the basic requirement of identifying which important diseases are present, this surveillance needs to estimate the level of disease. Specific surveillance techniques are required to produce accurate figures on the level of disease (discussed later in this manual).

Monitoring program effectiveness
Once a disease control program has been established, it is essential that surveillance be used to monitor the effectiveness of the program. For example, with a vaccination program, one might chose to monitor the proportion of the population with protective antibodies (aiming to see this rise to a level above which herd immunity is achieved, often around 80%), or one might monitor the cases of disease (aiming to see the number progressively decrease). If there is neither an adequate increase in protection nor a decrease in the cases of disease, it is a clear indicator that there are problems with the vaccination program that need to be investigated and corrected.

Case finding
Approaches to disease control vary depending on the disease, and sometimes depending on the stage of the disease control program. In the early stages of many programs, mass vaccination is used to decrease the level of disease. Later in the program, efforts may be made to find remaining infected animals or herds, and to remove them from the population ('test and slaughter'). This is an example of surveillance for which the purpose is case finding, and this may be used for a variety of diseases including brucellosis, tuberculosis and contagious bovine pleuropneumonia.

Exporting countries
Exporting countries are likely to be required to undertake specific surveillance activities to support their trade and meet the requirements of their trading partners. The types of surveillance that may be required by exporting countries include:
- Demonstration of freedom from disease
- Estimate disease prevalence for risk analysis
- Describe the distribution of disease to support zoning
- Early detection of disease incursions

Demonstration of freedom from disease
The most common requirement for an exporting country is to demonstrate that one or more diseases of concern to the importing country are not present.

Estimate disease prevalence for risk analysis
Under the rules of the World Trade Organization (WTO), it is possible to export animals from an infected country to an uninfected country if a risk analysis has shown that the risk of spreading the disease is low enough to be acceptable. Demonstrating freedom from disease in the exporting country means that the risk analysis is not necessary. However, if the disease is present, surveillance may be required to measure the prevalence of disease. This value is used in the risk analysis to determine if the risk of spread is acceptable.

Describe the distribution of disease to support zoning
Another alternative to facilitate trade when a disease is present in the exporting country is to establish a disease-free zone. Surveillance will be necessary to firstly identify areas of low prevalence to establish the zone, then to monitor disease eradication efforts to create the disease free zone, next to demonstrate that the zone is truly free from disease and finally to detect incursions to provide assurance that the zone remains free from disease.

Early detection of disease incursions
The ability to detect incursions of disease is a basic surveillance requirement of all countries. However, for exporting countries, the consequences of failing to detect an outbreak of disease are more significant as there is an increased risk that it could be spread to trading partners. Therefore, surveillance systems used for early detection of disease incursions in exporting countries may be put under closer scrutiny to assure importing countries that they are working effectively.

Importing countries
Under the WTO rules, countries are not able to establish trade barriers unless there is scientific evidence that trade will create an unacceptable risk of spreading disease. If a country wishes to prevent imports of animals or animal products from another country known to have a particular disease, the importing country must either demonstrate that it is free from that disease, or that an effective disease control program is in place. Surveillance will be necessary in both cases.

Required international reporting capabilities
Countries may be required to report disease outbreaks or disease status to a variety of international organisations. The standard for reporting surveillance data is set by the World Organisation for Animal Health (OIE). OIE requires two different types of reports:
- Immediate notification of the occurrence of new, emerging or exotic diseases, and
- Regular (monthly or six-monthly) notification of those diseases which are present and those which are absent from the country.

These requirements closely match the basic surveillance requirements of every country. In order to meet international reporting obligations, a country must be able to detect new incursions, and identify which diseases are present in their country.

Diseases that are absent
OIE regular reporting also requests information about which diseases are absent, and this surveillance is a little more complicated. Disease status may be classified in several ways:
- Present: cases of the disease have been diagnosed in the country
- Absent: surveillance has been undertaken and has demonstrated (with a specified probability) that the disease is not present in the country
- Unknown: no cases have been reported, but no surveillance has been undertaken to demonstrate freedom.

Clearly when the status of the disease is unknown, trading partners will be very cautious about importing from that country. In order to claim disease free status, specific surveillance (beyond the basic surveillance required by every country) usually needs to be undertaken.

Resources for surveillance
In addition to understanding the types and objectives of surveillance required by a country, it is also important to have a clear understanding of the resources required to implement surveillance. In many cases, weaknesses

in a national surveillance system are due more to resource constraints than a lack of understanding or planning of surveillance programs.

In general terms, the main resources required to implement effective surveillance are:
* *Human*
  ◊ Veterinary service staff at different levels, including field staff as well as program management, data processing, analysis and reporting staff and key decision makers
  ◊ Other participants in the surveillance system, including farmers, abattoir operators, market managers and so on.

* *Financial*
  ◊ Budget for the implementation of surveillance activities. In most cases, this comes from the government, but in some countries there may be cost sharing with animal industries.

* *Transport and communications*
  ◊ Transport to get veterinarians into the field to respond to disease reports and investigate disease outbreaks.
  ◊ Transport to get specimens to the laboratory for analysis.
  ◊ Communications (including telephone and internet) for rapid disease reporting and efficient data transfer.

* *Laboratory*
  ◊ While clinical and syndromic surveillance can be very useful, it is essential that, for key diseases, a diagnosis can be supported by laboratory confirmation.

Even if these different resources are present, the effectiveness of the surveillance system depends on the nature of these resources, particularly in terms of:
* *Quality*
  ◊ Are field staff adequately trained to perform their surveillance functions?
  ◊ Does the laboratory have the capacity to provide reliable diagnoses?
  ◊ Is the communication system (phone or internet) reliable enough for practical use?

* *Amount*
  ◊ Are there enough field staff?
  ◊ Are there enough laboratories?
  ◊ Is the budget adequate?

* *Distribution*
  ◊ Are the veterinary staff where they need to be? Are they located in the districts with ready access to farmers, or are they mostly concentrated in provincial offices?
  ◊ Does the transport infrastructure provide adequate coverage of the animal production areas?
  ◊ Is the budget appropriately distributed? Are funds retained mostly by the central office, leaving the field infrastructure under-resourced?
  ◊ Are laboratories located where they are needed?

Ways to address some resource constraints

When resources are inadequate, it is very difficult to implement effective surveillance. Addressing resource constraints can be difficult, as it usually requires extra funding, and financial resources are often the ones that are most limited. Nevertheless, there are some approaches that can be used to try to improve the situation when resources are scarce.

Human resources
* Not enough veterinary staff
  ◊ Train and employ more veterinary staff.

◊   This is expensive, slow and may be unfeasible.
-   Develop a system that allows surveillance to be supported by non-veterinary staff
-   Village animal health workers can act as a link between farmers and the veterinary service.
-   Syndromic surveillance with reporting of signs by non-veterinary reporters provides another approach.
-   The use of non-veterinary government officials to act as links between local communities and the veterinary services has been used in some countries.
-   Investing in improved transport (including mobile disease investigation units) to ensure that the few vets that are available are able to provide services where required.

•   Poorly trained staff
◊   Develop ongoing in-service training to improve skills. This may be in traditional veterinary areas (disease diagnosis and management), as well as specific functions (e.g. disease investigation and reporting, information management etc.)
◊   Improve feedback mechanisms so that field staff learn from each sample they submit and have a chance to improve their diagnostic skills.

•   Staff in the wrong locations
◊   Redeploy staff to areas that are currently underserviced.

Financial resources
In many developing countries, financial resources for surveillance come from either the national budget or for projects funded by international donor organisations. International projects can be a valuable source of extra funds to improve surveillance systems. However in almost all cases, these funds are linked to time-limited projects, and once these projects have finished, the funds are no longer available. Unfortunately, the most common result is that improvements made using donor funds cannot be sustained and the quality of surveillance decreases after the end of the project.

For this reason, it is recommended that:
•   Essential surveillance activities should be funded using ongoing funding from the national budget.
•   When donor funds are available, they should not be used to underpin essential surveillance requirements (as this means that essential systems will fail at the end of the project). Instead, they should be used to support:
◊   Sustainable improvements (such as training of staff, or improvement of laboratory capacity), or
◊   Important ad hoc surveillance activities (using, for example, surveys).

The use of project-based donor funds to provide, for example, incentives for field staff to make routine monthly reports provides a short term improvement to a surveillance system. However, when the project and incentive payments stop, this will provide an active disincentive for field staff to continue reporting.

Based on these recommendations, it is therefore essential that the sustainable national budget for surveillance should be adequate to support all ongoing essential surveillance activities (these are discussed later in this manual). If the existing budget is not adequate, how can this be addressed?

Persuading decision makers that more budget is needed to support the surveillance system is, in a way, the same as persuading any stakeholder to participate and fulfil their role in a surveillance system. This involves first identifying what we need the stakeholder to do (provide more budget), and then to understand their motivations and the costs and benefits of making such a decision. Clearly, the budget decision makers have many other activities that deserve funding and a limited budget to allocate. In order to increase the surveillance budget, they must be convinced that this is a good way to spend money. Convincing the appropriate decision makers involves:
•   Gathering evidence that surveillance is cost effective. The argument can be made that surveillance saves money (by allowing rapid response to disease outbreaks and thereby minimising the losses associated with them), rather than costs money.
•   Presenting this evidence in a form that is tailored to the decision-makers. Such people (for instance the

Minister), are busy, and need to be provided with the key information as succinctly as possible. A one or two page clear and convincing document will be much more effective than a comprehensive 60 page examination of the issues.

- Delivering the message in an appropriate way. Gaining access to the decision makers, and having the message delivered by somebody they trust can be an important factor in whether the process is successful or not. This depends on an in-depth understanding of the local political situation and target audience.

Laboratory resources

An effective diagnostic veterinary laboratory is very expensive. It requires an appropriate building, a wide range of expensive equipment, an adequate number of well trained staff, ongoing budget to support reagents and maintenance, as well as a steady flow of suitable diagnostic specimens to ensure that the skills of the staff are maintained. Problems with laboratories often include the number, the quality and the distribution.

The quality of a laboratory is often influenced by inadequate funding (to maintain equipment and supply reagents), inadequate ongoing staff training, and insufficient work-load to ensure that staff maintain high skill levels across a wide range of diagnostic tests.

Another problem is the inadequate number and distribution of laboratories. Transporting specimens over long distances, when the transport infrastructure is poor, is very difficult, and may mean that specimens are either not sent to the central laboratory or that they are in too poor a state to be analysed when they arrive. One solution that is often suggested is to build a network of regional laboratories so that the distance for specimen transport is less.

While this approach may have political appeal, in countries with limited resources, it is rarely the best solution. In fact, in many cases, the best solution is to have fewer laboratories rather than more. This is because the problems usually are:
1. Transport to the laboratories (a transport problem, not a laboratory problem), and
2. Inadequate budget, inadequate staff, inadequate training, and inadequate specimens for existing laboratories to operate effectively.

Instead of establishing new regional laboratories (which is cost-intensive and which would then suffer from the same problems as existing laboratories), the recommended solutions are:
- Decrease the number of laboratories. This may mean having only a single national laboratory.
- Using funds that were going to be used to build new laboratories to improve the training of staff and to support existing laboratories so they function well.
- Also from the money saved, spend more money on improving specimen transport (addressing the real problem), as discussed below.

The result will be a properly resourced laboratory that has an adequate flow of specimens to maintain high quality diagnostic services. In extreme cases where national resources are severely limited, it may even be better to have no national laboratory at all and instead, to use the services of regional reference laboratories or a nearby country's national diagnostic laboratory.

The key issue here is that the increased cost of rapidly transporting specimens to a national or regional laboratory will always be much less than the cost of establishing new laboratories, which run the risk of suffering from problems due to lack of resources.

In order to make such a system work effectively, it may be necessary to establish local specimen processing posts (for instance, in district offices). The role of these posts is to have minimum processing and packing equipment to allow safe and reliable transport of specimens: a centrifuge, transport media, slides, a refrigerator and freezer and packing material.

Transport and communication

Problems with transport are common. These include difficulties getting veterinary staff into the field to respond to disease reports, as well as problems getting samples from the field to laboratories. Possible

solutions to the problem of getting staff into the field include:

- The use of local agents, such as village animal health workers, to report disease by phone. When access is difficult, a clear description of the problem may be able to suggest possible solutions, and should be able to determine if the problem is likely to be serious or not. By eliminating non-serious problems, those transport resources that are available can be better used to focus on the most important problems.
- The use of a limited number of mobile disease investigation units. If local staff do not have the transport or skills to investigate a problem, a dedicated well trained mobile unit can focus on those reports of disease that are likely to be the most serious.

Specimen transport problems can be addressed by seeking new (and possibly more expensive) ways to transport specimens. As long as specimens are appropriately packed and preserved, they may be able to be transported inexpensively using local public transport, but this requires effective coordination with the transporter and laboratory staff and the destination. Alternatively, while admittedly expensive, hiring a long distance taxi may be an effective way to transport specimens, and is vastly cheaper than establishing a new laboratory.

Rapid and effective communication is essential for effective surveillance. The internet offers a valuable tool for rapid and early reporting of disease events, but there are many areas where the internet is not available. In most countries, mobile phone coverage has expanded rapidly, and a very high proportion of the population has access to mobile internet. This makes phone and SMS reporting feasible, however there may be a need to develop systems to reimburse reporters (farmers or veterinary staff) for the cost of these calls, to further encourage reporting.

Conclusions

All veterinary authorities should be able to identify the major diseases that occur in their countries, and to detect incursions of major exotic, new or emerging diseases. Beyond these basic requirements, surveillance needs depend on the individual needs of the country, and are commonly related to surveillance to support disease control programs, or surveillance to support trade.

CONCEPTS AND PRINCIPLES TO MEET SURVEILLANCE OBJECTIVES

There are many different possible approaches to surveillance, each with their own advantages and disadvantages. In order to determine which surveillance approaches may be useful for different objectives, it is necessary to be able to describe and compare surveillance approaches, based on a range of characteristics. Some important characteristics of surveillance include:

Timeliness
- This describes how rapidly the surveillance system is able to produce information, and is related to the periodicity of surveillance. Some surveillance activities are ongoing (data is being gathered all the time), while others are regular (for example, occur at monthly intervals), and yet others are ad hoc (surveillance is only undertaken occasionally, when the need arises).

Population coverage
- This describes what proportion of the population covered by the surveillance system. Some surveillance (e.g. surveys) is only able to sample a relatively small proportion of the population, while other systems have virtually full coverage.

Representativeness
- This describes whether the animals under surveillance are representative of the population or not. The surveillance sample may be:
  - ◊ Representative: the proportion of animals with disease or any other characteristic is the same in the sample as in the population.
  - ◊ Risk-based: the proportion of animals with disease in the sample is higher than the proportion of animals with disease in the population.
  - ◊ Biased: the proportion of animals with disease in the sample is not the same (usually lower) than the proportion of animals with disease in the population.

Representative	Prevalence in population	=	Prevalence in sample
Risk-based	Prevalence in population	<	Prevalence in sample
Biased	Prevalence in population	≠	Prevalence in sample

Using these and other characteristics of surveillance systems, it is possible to define the requirements of surveillance in order to meet different purposes.

Early detection

The objective of early detection is to identify disease rapidly before significant spread. Rapid detection means that the surveillance system used must be gathering data in an ongoing manner. Surveillance that takes place, for example, annually or on an ad hoc basis may detect disease, but it is possible that the disease has been present since the last round of the surveillance.

The definition of 'early' is related to the rate of disease spread. While it may be overly ambitious to aim to detect the very first case of disease, detection within the first three or four generations of spread is desirable. With a disease with a pre-patent period of five days, surveillance would aim to detect the disease within 15 to 20 days of the first case. For a slow moving disease, with a pre-patent period of 6 months, 'early' detection

may mean detection within two years of the first case.

While some populations may be at higher risk of being infected than others, it is impossible to predict which individual animals will be the first to be infected with an exotic, new or emerging disease. In a country with millions of animals in tens of thousands of herds or flocks, which should be kept under surveillance for the purpose of early detection? If an identified high-risk group is examined, it is always possible that the first outbreak occurs in animals in the lower risk group. Furthermore, for new diseases, it is impossible to know which animals are at higher risk.

The answer to this problem is simple. For effective early detection, the entire population (or as much of the population as possible) should be under surveillance. This is known as a surveillance system with comprehensive coverage.

The effectiveness of surveillance for early detection is described in terms of sensitivity. The sensitivity of a surveillance system is defined as the probability that the system would find disease in the population if it is infected at a specified level (the design prevalence). Thus, a surveillance system with 95% sensitivity at 1% design prevalence has a 95% chance of detecting at least one infected animal in the population, if 1% of the population is infected. For a poultry disease, if there are 10 million domestic poultry in the country, a design prevalence of 1% is equivalent to 100,000 infected animals. Clearly, having so many infected animals in the population before the disease can be confidently detected does not represent 'early detection'. For early detection, the design prevalence is normally very low. In this example, our early detection system would aim to detect the first flock or village that becomes infected, maybe consisting of 1,000 birds, which represents a design prevalence of 0.01%.

In summary, for early detection, the surveillance system should:
* be continuous,
* have comprehensive coverage of the population, and
* be sensitive with a very low design prevalence.

Demonstration of freedom
It is useful to be able to demonstrate freedom from disease for a variety of reasons, as described in the section "*Demonstrating freedom from disease*" (trade support, stopping control measures etc.). In contrast to early detection, the need to provide evidence of freedom from disease only arises from time to time. For instance, when negotiating trade agreements, or deciding whether to stop control measures, evidence may be required. However, new evidence is not required the next day, the next week or the next month. Often, it may be necessary to update the evidence to show that the disease has not entered the country since the last surveillance, but this can occur intermittently or at regular intervals. Ad hoc surveillance or surveillance at regular intervals is normally adequate to demonstrate freedom from disease. Continuous surveillance is not required, but if such systems exist, they can contribute to demonstration of freedom from disease.

The design and analysis of surveillance to demonstrate freedom and for early detection are both similar. The effectiveness of both are measured using sensitivity, but the design prevalence when demonstrating freedom from disease is set either using international standards or agreement between trading partners. The design prevalence values used depend on how quickly the disease spreads, but are typically higher than those used for early detection (e.g. 1%, 5% or 10%).

Unlike early detection, which may be seeking to detect a new, unknown disease, surveillance to demonstrate freedom normally focuses on a single specified disease. Those designing the surveillance therefore normally have a good understanding of risk factors that influence the disease, and can identify populations that are more likely to be infected if the disease were present in the country. Using this knowledge it is possible to design risk-based surveillance, in which the animals included in the surveillance are selected from high-risk groups. Risk-based surveillance provides a more efficient approach to demonstrating freedom from disease. Compared to representative sampling, risk-based sampling can achieve the same sensitivity using a lower sample size, and is therefore less expensive.

In summary, surveillance to demonstrate freedom from disease:
- does not need to be continuous, but instead may be ad hoc or intermittent
- can use risk-based sampling to increase efficiency
- uses a higher design prevalence than early detection

Measuring disease

The reasons for measuring the level of disease were discussed on page 7. Often prevalence or incidence estimates are used for comparison – to detect changes in the level of disease over time, geographically, or related to other risk factors.

For example, in a disease control program, it may be useful to compare the incidence of outbreaks before the start of the control program to the incidence after the program has been implemented. If the incidence has gone down, that is an indication that the control program is working. If the incidence has remained the same (or has gone up), this suggests that there are problems with the control program that need to be fixed. Continuing the control program if it is not improving the disease situation is simply a waste of money.

The decision about whether the control program is working depends on comparing two measures of disease – incidence before the start of the program and incidence after the program is introduced. In order to be confident that one is making the right decision, one must be confident that the two measures of incidence are correct.

There are two reasons why a measure of disease may be incorrect:
Bias or systematic error
- An estimate of prevalence or incidence is biased when it systematically gives the wrong answer. This may be because the way the sample was selected (e.g. use of a biased or risk-based sample), the way values were measured (e.g. problems with the diagnostic test) or the way the data were analysed.

Lack of precision or random error
- Random error occurs due to the random nature of the selection of animals in surveillance. If a sample is selected multiple times, sometimes, the prevalence may be a little higher, and sometimes a little lower, just through the chance selection of animals. Using a larger sample size will result in a more precise (and therefore reliable) estimate.

In order to be used reliably, surveillance that aims to measure disease must try to avoid both of these errors; it should avoid bias and have adequate precision.

Representative sampling (for instance using formal random selection) is one of the only effective ways of avoiding selection bias. When reliable measures of disease are required for decision making, surveillance should always be based on representative sampling.

However, representing sampling is often difficult and expensive. It is possible to get estimates of prevalence or incidence from surveillance that is not based on representative sampling, but these estimates are likely to be biased. For example, when surveillance aims to detect changes in the level of disease over time, any changes observed may be due changes in the level of disease, or may be due to changes in the bias present (e.g. an increase in the reporting rate for the disease). It is nevertheless possible to use biased surveillance data to make comparisons, using caution and some assumptions.

For example, the veterinary services wish to compare the level of disease prior to the start of a disease control program to the level after the program has been introduced. However, rather than using estimates from representative surveillance (e.g. a structured survey), they choose to use biased data (e.g. from a passive reporting system). The data is biased because of underreporting. The apparent prevalence of disease before the control program, according to the disease reports received, is 5%. However, the true level of disease is higher as many cases are not reported. If only 50% of cases are reported, the true prevalence of disease would be about 10% (unfortunately we almost never know the level of underreporting).

After the control program has been introduced, the number of reports of disease are again analysed to calculate an estimated prevalence of 3%. If the level of underreporting has remained constant at 50%, then an apparent decrease in prevalence from 5% to 3% would be due to a true decrease in prevalence from 10% to 6% - indicating that the program is working. In this example, due to underreporting, we don't know the true level of disease, but if the level of underreporting is constant, we will see a decrease in the reported level of disease and this indicates that the program is working.

This simple approach is commonly used when only passive disease reports are available. The problem is that our assumption (that the level of underreporting is constant) may or may not be correct. For example, if the observed number of reports after introduction of the control program is still 5% (the same as before the control program), there could be several reasons:
- There has been no change in the true level of disease, and no change in the reporting rate.
- The true level of disease has gone down (the control program is working), but the level of reporting has gone up (perhaps because of increased awareness as a result of the control program.
- The true level of disease has gone up (the control program has failed), but the level of reporting has gone down (perhaps because overly aggressive control measures have resulted in farmers hiding cases of disease).

As we virtually never know the true level of underreporting and how it might change, it is very difficult to determine which of the three possibilities is true. If the decision is important, it is worth spending the extra money to use representative surveillance to get a reliable answer. On the other hand, if the decision is less critical, the experience of field officers may be adequate to indicate if the reporting rate is changing, and so justify any assumptions. In practice, biased data are often used to make comparisons, but if this is done, the veterinary authorities should consider carefully:
1. what assumptions are being made;
2. whether these assumptions are likely to be valid; and
3. the consequence of making a wrong decision on the basis of biased data.

As with demonstration of freedom, disease measures are not required constantly, but are needed to make specific decisions. For instance, in a control program, a measure of the level of disease is required before the program starts (as a baseline), and then at regular intervals during the operation of the program (perhaps annually).

In summary, surveillance to measure disease:
- Does not need to be continuous but can be ad hoc or periodic;
- Should be based on representative sampling to avoid bias; and
- Should use a big enough sample size to give adequate precision.

Case finding

Case finding, or identifying individual infected animals, flocks or herds, is normally a part of surveillance during a control program. In public health, these programs are common for early detection of preventable diseases (for example, bowel, breast or cervical cancer screening programs). In animal health, case finding is used in test and slaughter programs, progressive eradication through herd accreditation schemes, or public health surveillance programs in abattoirs (e.g. BSE testing or Trichinella surveillance).

Within a control program, case finding activities are normally continuous (but periodic campaigns can also be used). The aim is to remove all infected animals from the population, and therefore the entire population needs to be included in the program. Case finding is therefore usually based on comprehensive surveillance. For instance, all animals in a herd are tested, and, progressively, all herds in the population are tested. Nevertheless, it is possible to use risk-based approaches to improve the efficiency of case finding surveillance. This involves identification of populations with a higher risk of being infected, and applying more stringent surveillance to those populations to increase the chances of finding cases of disease.

The effectiveness of case finding surveillance depends on the sensitivity of test used to identify cases. Sensitivity is important for early detection or demonstration of freedom, but in these cases, we are interested

in the surveillance sensitivity – the probability that surveillance will detect at least one infected animal if the population is infected. In case finding surveillance, we are interested either in the individual sensitivity – the sensitivity of the tests used to identify individual animals as infected or not – or the herd sensitivity when the 'case' is an infected herd.

The quality of the surveillance is measured in terms of the detection fraction – the proportion of infected animals or herds in the population that are successfully detected by the surveillance program.

In summary, case finding surveillance should:
• use comprehensive coverage of the population, although risk-based approaches can focus on high risk parts of the population;
• be ongoing (or periodic if the period of infection is long or rate of spread is slow); and
• have good individual herd or animal sensitivity.

The requirements for different surveillance purposes are summarised in the figure below.
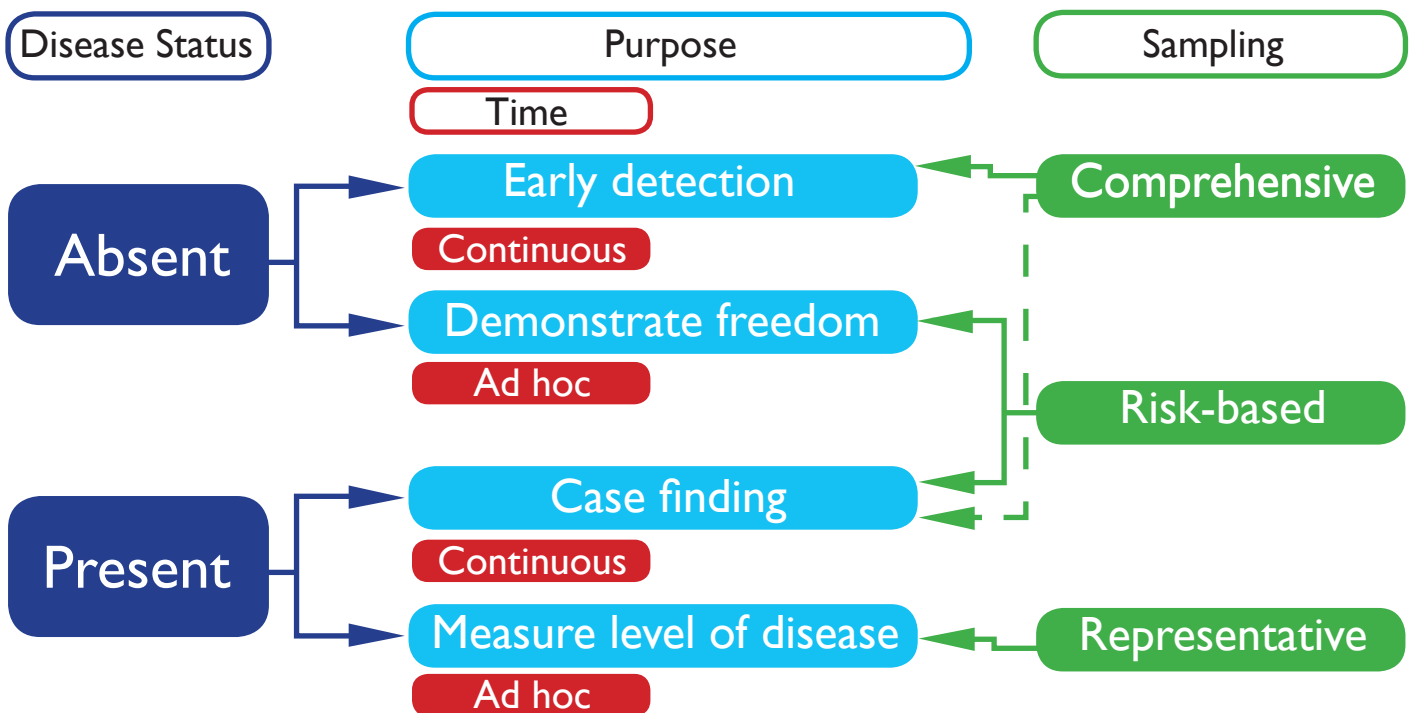
ESSENTIAL SYSTEMS

Required capabilities
The basic surveillance capabilities of a functional veterinary service are:

Continuous surveillance
• to detect incursions of exotic, new or emerging diseases
• to identify the major diseases present in the country

Surveillance conducted when required (periodic or ad hoc)
• to measure the level of disease
• to detect changes in the level of disease over time
• to detect differences in the level of disease in different geographical areas
• to identify other factors influencing disease
• to demonstrate freedom from disease
• case finding as part of a control program

Surveillance tools
This chapter examines the available approaches to animal disease surveillance. The aim is to identify the characteristics of the main surveillance tools available, to decide which combination of surveillance tools is best able to meet the required surveillance capabilities.

Classification of surveillance tools
Approaches to surveillance have been classified in many different ways based on, for example, sampling approaches, cost, periodicity, disease focus, data gathered and so on. The characteristics of key surveillance systems will be discussed in part 2 of this manual.

One useful to classify surveillance is to describe who makes the primary observation and how frequently these observations are made. The possibilities are that the primary observations of animals are made by:

Farmers or owners
• The owner of the animals sees them frequently, usually at least every day. Surveillance based on observations by the owner can therefore be considered continuous.
• Veterinarians or agents of the veterinary services
• Veterinarians only come into contact with the animals intermittently and cannot be in full time contact. Surveillance in which veterinarians make the primary observations is therefore periodic or ad hoc.

This classification is equivalent to the more commonly used classification of active / passive surveillance. Where farmers make the primary observation, it is passive surveillance. They may ask a veterinarian to visit to examine the animal and provide treatment, but the first person to gather information from the animal was the farmer.

When a veterinarian makes the first observation, it means that the veterinarian is examining the animal without first having been alerted to any problem by the owner. The purpose for the examination (whether it is a clinical examination or the collection of blood or other specimens for laboratory analysis), is surveillance, and this represents active surveillance by the veterinary services. Veterinary services do not have enough staff to be in direct contact with all the animals in the population all the time, so active surveillance is necessarily ad hoc or periodic.

Surveillance based on farmer observations
The most important and most common surveillance system based on farmer observation is the passive farmer disease reporting system. When a farmer or animal owner observes that their animals are sick or behaving abnormally, they may contact the veterinary services to seek assistance. This leads to a report which may be used for surveillance. There are two important features of the passive farmer disease reporting system:
• It is continuous. In most situations, famers are in contact with their animals every day. If disease occurs, they will recognise it rapidly.

- It is comprehensive. Virtually all the farmed animals in the country are covered by this surveillance system. In some production systems, animals may not be observed for extended periods, but the vast majority of animals are observed regularly.

These two features (continuous surveillance and high coverage) represent important advantages for surveillance. However, surveillance based on passive farmer reporting has a number of important weaknesses as well. Strategies to overcome these weaknesses are discussed in part 2 of this manual. However, a number of other approaches to surveillance have been developed, based on the use of farmer observations, to overcome some of the weaknesses of farmer passive reporting. These include:

- **Participatory disease surveillance (PDS).** This still depends on farmers' observations of their animals but addresses weaknesses in passive reporting by making the reporting active. The veterinary services visit the farmers to ask about their observations, rather than waiting for farmers to report the problem themselves.
- **Syndromic surveillance.** In some forms of syndromic surveillance, observations of non-veterinary reports (e.g. famers) are recorded and analysed to detect abnormal patterns, triggering an investigation. The primary observer is still the farmer, but this approach optimises the use of resources by only launching a detailed investigation when there is evidence that something unusual is happening.
- **Laboratory surveillance.** This improves the quality of information from the field by confirming the diagnosis with laboratory tests. The initial report of disease still comes from the farmer, and samples are collected for testing during the follow-up investigation.
- **Zero reporting.** This approach to surveillance is based on farmers' observations that disease is not present in their animals.
- **Sentinel veterinary practices.** This approach aims to overcome poor reporting rates by collecting complete information from a sample of veterinary practices. The primary observations are made by the farmers, and follow-up is made by the private veterinary practices.
- **Telephone hotline or SMS reporting.** These systems address problems with slow transmission of disease reports through a hierarchical reporting system and allow urgent reports to be passed directly to the central level. The Dutch CattleWatch telephone hotline is an advanced version of this system.
- **Indirect surveillance.** This approach is based on the use of existing data which may act as an indirect indicator (or proxy) for disease – for example, records of the sales of antibiotic feed additives may increase when farmers perceive a disease problem.

These variations on the passive farmer disease reporting system are discussed in more detail in part 2 of this manual.

Surveillance based on veterinary observations
When the primary observation is made by a veterinarian (or an agent of the veterinary services) it means that the animals are being examined without first having been recognised as having a disease by the farmer. This is active surveillance and normally takes the form of a structured survey, organised by the veterinary services, and designed to collect specific information to answer a specific question.

As surveys are organised and implemented by the veterinary services, they can be designed to overcome many of the weaknesses of passive surveillance systems. Key advantages of structured surveys include:
- They can detect subclinical disease or evidence of previous disease (antibody status) by collecting specimens for laboratory testing.
- They can collect high quality focused information to respond to a specific question.
- The sampling strategy can be designed to meet the specific needs of the survey.

Disadvantages include:
- They can be expensive and difficult to organise.
- They can only cover a relatively small sample of the population (low coverage).
- They are carried out over a defined period and normally cannot be continuous.

If the purpose of the survey is to measure the level of disease, representative surveillance using random sampling can be used to ensure that there is no selection bias. The sample size can also be planned to achieve

the required precision. This ensures that the results of the survey are reliable and can be confidently used for planning veterinary policy.

On the other hand, if the purpose of the survey is demonstration of freedom from disease, a risk-based sampling strategy can be used to achieve a higher sensitivity with a lower sample size.

Nature of the disease
The nature of the disease under surveillance plays an important role in the choice of surveillance approach.

Clinical signs
Passive farmer disease reporting systems depend on farmers being able to identify animals as being sick, and then reporting this to the veterinary authorities. These surveillance systems will not work if
- The infection or condition does not show clinical signs. For instance, in a disease eradication program, the disease may sometimes have a carrier state where animals are infected but do not show signs. Farmer disease reporting may identify the clinical cases, but will not be able to identify subclinical cases.
- The signs of the disease are similar to those shown in diseases that are considered 'normal' or unimportant. For instance, in an area that suffers from frequent outbreaks of Newcastle disease causing high rates of sudden mortality in village chicken flocks, highly pathogenic avian influenza (HPAI) may cause outbreaks that appear to be very similar. If the poultry owners consider periodic high mortality to be normal, they are unlikely to report mortality that may be associated with HPAI. In this case, farmer passive reporting may be less effective, unless efforts are made to encourage reporting of all mortality events.

Known or unknown disease
The early detection of disease incursions is an important component of surveillance in all countries. Surveillance for exotic diseases often uses specific laboratory tests aimed at detecting antibodies or antigens. However, early detection surveillance also aims to detect new, previously unknown diseases. Naturally there are no laboratory tests available for new diseases, as they have not yet been identified. The only way to detect a new disease is through clinical surveillance, which may then be followed up by laboratory investigation to identify the agent.

Active surveillance using representative or risk-based surveys may sometimes use clinical examination but more commonly use laboratory tests to detect disease. Laboratory tests can be divided into general tests capable of identifying a wide range of diseases (e.g. post mortem or histopathology), and specific tests that identify only one disease (e.g. ELISA, complement fixation, or PCR). Surveillance based on the use of specific laboratory tests is not suitable for detecting new diseases.

What surveillance approach to use?
This brief discussion of different approaches to surveillance has identified some strengths and weaknesses with the main passive and active surveillance tools. In order to decide which tools are best to use as part of a national surveillance program, it is necessary to match the tool to the surveillance requirements.

Tools for different requirements
The tools that may meet different surveillance requirements are summarised below:

Early detection
- **Passive farmer disease reporting** systems are the best tool for early detection (when they are functioning effectively) because they have comprehensive coverage of the population, and are continuous. The coverage of surveys is too low to provide assurance of identifying incursions quickly. Laboratory surveillance using specific tests is not able to detect new disease.

List diseases present
- **Passive farmer disease reporting** systems are an inexpensive and effective way to identify which major diseases are present, although they are not able to provide unbiased measures of the level of the disease.

Change in disease over time
- **Passive farmer disease reporting** systems are suitable to get an indication of the change in the level of disease over time, if it can be assumed that the level of underreporting is approximate constant, and the decisions that are made using the estimates are not critical.
- **Representative surveys** are required to get unbiased measures when important decisions are being made.

Geographical variation in disease
- **Passive farmer disease reporting** systems are suitable to get an indication of the geographic distribution of disease, if it can be assumed that the level of underreporting is similar between different areas, and the decisions that are made using the estimates are not critical.
- **Representative surveys** are required to get unbiased measures when important decisions are being made.

Unbiased measure of disease
- **Representative surveys** are the only way to get reliable unbiased measures of disease and should be used when important decisions are being made.

Freedom from disease
- **Passive farmer disease reporting** systems can provide evidence for freedom from disease if suitably analysed, but only for diseases that show clear clinical signs that cannot be easily confused with the signs of common endemic disease.
- **Risk-based surveys** are an efficient way to demonstrate freedom from disease, and should be used when there may be subclinical disease or when signs could be confused with those of endemic diseases.

Case finding
- **Passive farmer disease reporting** systems are useful for case finding as they are continuous and have comprehensive coverage. They are not useful of subclinical diseases or diseases with signs similar to endemic diseases.
- **Risk-based surveys** may be used for case finding for subclinical diseases or those without unusual signs. However the coverage that can be achieved by a survey is often too low to find a significant proportion of the cases in the entire population.

The match between the available surveillance tools and the surveillance requirements is summarised in the following diagram.

Clinical disease with unusual signs / **Subclinical or disease common signs**

Rows: Passive farmer reporting, Representative survey, Risk-based survey

Column headers: Early detection, Exist diseases present, Change over time, Geographic variation, Unbiased measure, Freedom from disease, Case finding

Legend:
- ✕ Unsuitable
- Poor
- Moderate
- Good
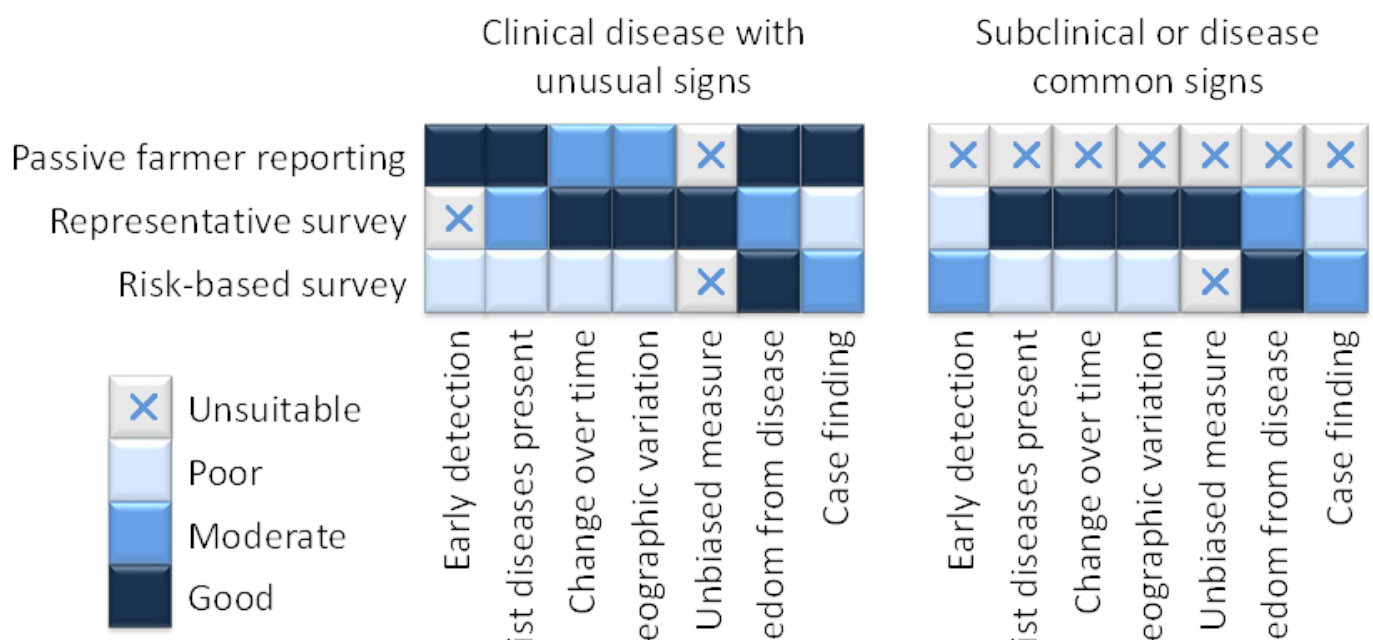
General recommendations for surveillance

Passive farmer disease reporting system
- All countries should use this system for:
  ◊ Early detection of disease incursions
  ◊ Identifying what major diseases are present in the country

- It may also be useful for
  ◊ demonstrating freedom from disease (clinical disease only)
  ◊ case finding as part of a control program (clinical disease only)
  ◊ estimating changes in the level of disease over time (if reporting rates are assumed to be constant over time)
  ◊ estimating geographic variation in disease (if reporting rates are assumed to be similar between regions).

Variations of systems based on farmer observations (for example, indirect or syndromic surveillance)
- These may be used, if data is available, to overcome specific problems with the standard farmer reporting system.

Representative surveys
- These should be used, when required, to:
  ◊ make reliable unbiased estimates of the level of disease
  ◊ confidently identify changes in the disease over time
  ◊ confidently detect differences in disease between regions

- These are more expensive and more difficult, and should only be used when important decisions depend on reliable information

Risk-based surveys
- These should be used, when required, to:
  ◊ Demonstrate freedom from disease, particularly when a subclinical (e.g. carrier state) may exist. For clear clinical disease, passive farmer disease reporting systems are often less expensive and more sensitive.

- They may also be useful for:
  ◊ case finding, although coverage is often low.

These recommendations are summarised in the diagram below.
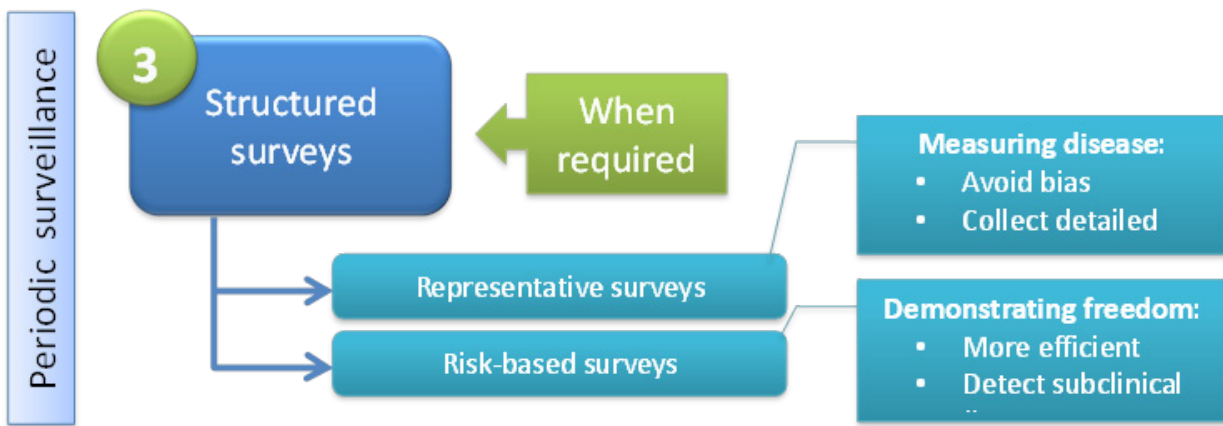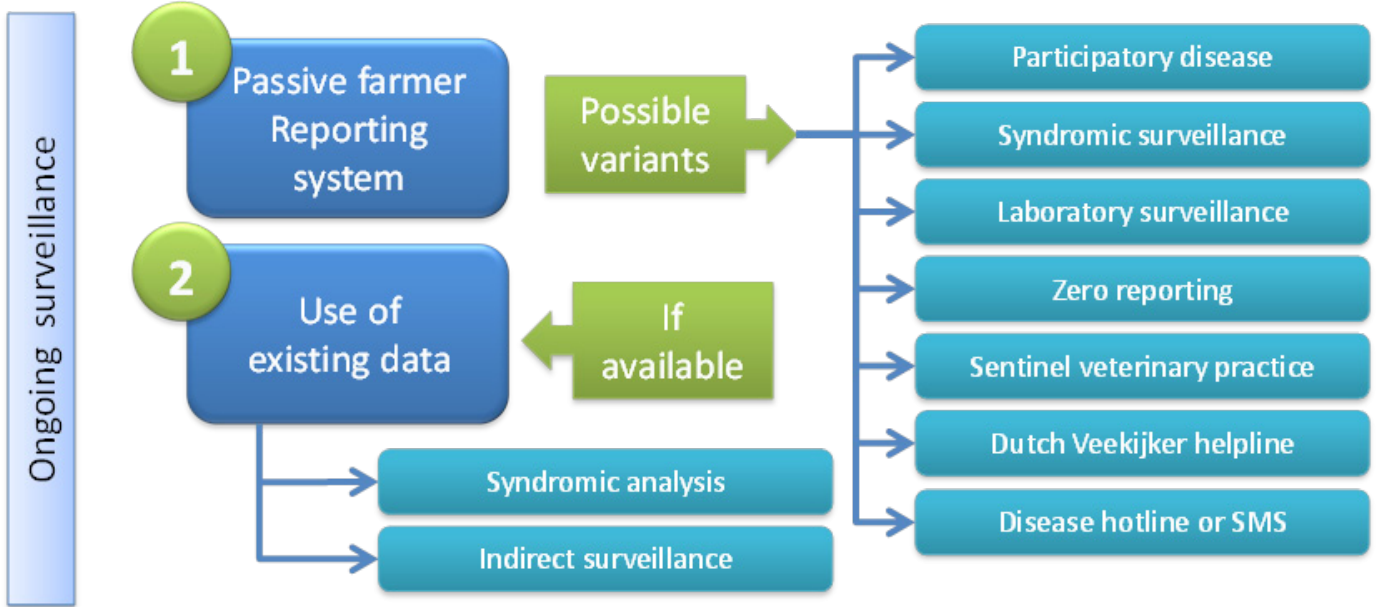
PART 2:
BASIC COMPONENTS

FARMER REPORTING SYSTEM

Quick guide

This is a quick step-by-step guide to developing an effective basic famer disease reporting system.

1. Ensure that there are field staff able to be contacted by farmers in need of assistance with disease problems
2. Provide standardised reporting forms for field staff to report cases to the central level
3. Develop a communication pathway to transmit information from the field to the central level
4. Facilitate farmer reporting
5. Inform farmers that field staff are able to assist with problems
6. Ensure that farmers get benefit whenever they contact the field staff for help
7. Facilitate veterinary service reporting
8. Ensure veterinary service staff know their role in the system
9. Ensure that field staff get benefit whenever they submit a report
10. Establish a system for managing and analysing data from reports
11. Ensure effective feedback systems to provide useful and encouraging information back to field staff and farmers
12. Ensure that data is analysed and reported to decision makers in a form that is easy to understand and useful for making important decisions
13. Monitor the performance of the reporting system
14. Reward participants that actively use the system
15. Identify weaknesses and take steps to correct them

What is it good for?

A passive farmer disease reporting system is good for:

- Early warning of diseases that show clear and unusual clinical signs, or have major impacts (and are therefore very likely to be reported by farmers).
- Demonstration of freedom from diseases that show clear and unusual clinical signs, or have major impacts (and are therefore very likely to be reported by famers). In particular, passive farmer reporting is virtually the only tool available for early warning of new (previously undescribed) diseases, as no specific tests are available.
- Identifying what significant diseases are present. If the field veterinary and laboratory services are capable of making reliable diagnoses, passive farmer reporting is a good way to identify the commonly recognised diseases present in a country. However, due to reporting biases, the relative frequency of reporting of different diseases does not necessarily indicate the relative prevalence of each disease.
- Detecting changes in disease over time. Reporting biases mean that the number of reports of a disease may not accurately reflect the real prevalence of that disease. However, if the bias is approximately constant over time, an increase in the number of reports is likely to be due to an increase in the real number of cases. It is important to consider other possible reasons for changes in reporting frequency (such as increased awareness, a change in field staff and so on).
- Case detection. Passive farmer reporting systems have very high coverage so are amongst the best system for case detection. However this is only valid for diseases that are likely to be reported (diseases with clear clinical signs that are not easily confused with other common diseases, or for which there is high farmer awareness).

What is it not good for?

- Early warning of diseases that show no clinical signs, have very little impact, or have signs which are very easily confused with existing common diseases. No system is very good at guaranteeing early detection of these types of disease but those that have the best chance are:
  ◊ Abattoir surveillance for those diseases that can be picked up at ante-mortem or post-mortem inspection (because of the high coverage of abattoir surveillance), or
  ◊ Risk-based surveys targeted at a particular disease, as they are able to use, for example, serology which can identify past subclinical infection.

However, neither approach is reliably able to identify subtle or subclinical diseases before significant spread

has taken place.
- Demonstration of freedom from diseases that show no clinical signs.
- Reliably measuring the change in disease over time. While passive reporting can indicate a change, that change may be due to a change in the level of reporting rather than a change in the level of disease. To confidently assess a change in the level of disease, it is necessary to have unbiased measures, based on representative surveys.
- Confidently prioritising disease. Passive systems can identify those diseases that are present, but because of varying reporting rates, just because one disease is reported more frequently than another, it doesn't necessarily have a higher prevalence. Representative surveys are required to accurately measure the true prevalence of different diseases for prioritisation.

Introduction to farmer reporting

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. They are 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. They are 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 and it is general surveillance capable of detecting any clinical 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 observes 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 him/her 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.

5. 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.

6. 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 diseases reported each year, as well as reports to meet international reporting obligations.

7. 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
- description of 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 respond 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 the following:
  - ◊ 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 problem. 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.
- The 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 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 that there is not much disease and that most of this disease is on well managed farms. However, in reality there is probably quite a lot of disease and 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. Both of these measures are based on the count of the number of cases of disease (the numerator, or the number on top of a fraction), and the population (the total number of animals or farms, or the total at risk of getting the disease, which is the denominator, or the number on the bottom of a fraction).

For example, if there were 300 sick animals in a population of 6,000, the incidence would be 300/6,000 or 5%, made up of the numerator (300) and the denominator (6,000). 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 of which are related to disease. For example, 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. For example, 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.

Failure to report can be classified into three main reasons:
- Knowledge: Famers don't know that they can report or that they should report.
- Capacity: Farmers are not able to report, even when they know they should.
- Refusal: Farmers don't report, even when they know they should report and they are able to report.

Knowledge

The farmers may be unaware that they should report, or that the veterinary services are able to help with their disease problem. Alternatively, the farmers may not know that their animals are sick due to subclinical disease, or animals not under close supervision (such as animals grazing unattended in a forest for an extended period).

Capacity

Farmers 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, or seasonal conditions making travel impossible.

Refusal

Farmers may refuse to report due to:
- Fear of the consequences of reporting. This fear may be due to imagined consequence, or may be based on actual experience. Farmers may fear:
  ◊ That diseased animals may be slaughtered
  ◊ That no compensation will be paid
  ◊ That he farm will be quarantined and sale of animals prohibited
  ◊ Dealing with the government in general
  ◊ 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, but reporting disease may cause panic selling, and lower the market price
- Apathy. The farmer may simply not care about reporting or the health of their animals.
- 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.

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 2,000 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 importance 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 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 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 than 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 which is extremely unlikely).

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 (for example, 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. Routine reporting cycles. 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. For example, 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 1,000 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 40 outbreaks in one province, where 80% of villages have been vaccinated and 10 outbreaks in another province of similar size where 65% of villages have been vaccinated, as summarised in the table below.

	Province 1	**Province 2**
% villages vaccinated	80%	65%
Number of FMD outbreaks	40	10

It may therefore appear that the vaccination program is not working. The lower the vaccination coverage, the fewer 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 percent 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 included the name of the village vaccinated, it would be possible to match this data for more detailed analysis. This may reveal the following data:

Province 1	**Outbreak**	**No outbreak**
Vaccinated	2	318
Not vaccinated	38	42

Province 2	**Outbreak**	**No outbreak**
Vaccinated	1	129
Not vaccinated	9	26

Analysing this data shows that the proportion of vaccinated villages with FMD outbreaks is 2/320 (or 0.625%) in province 1 and 1/130 (or 0.769%) in province 2. In contrast, in non-vaccinated villages, the proportion suffering outbreaks is 47.5% in province 1 and 25.7% in province 2.

This indicates that those villages that have been vaccinated have been very well protected from outbreaks of FMD (with only 3 vaccinated villages suffering an outbreak). However unvaccinated villages had a high chance of having an outbreak.

The implications for the control program are that:
• Vaccination procedures appear to be working quite well. There is unlikely to be a problem with the vaccine, the cold chain, the vaccination technique or the coverage within vaccinated villages.
• The continued outbreaks of FMD are due to the fact that not all villages are being vaccinated.

If the simple analysis had been done based on summarised data, 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 buy better vaccine, improve the cold chain, or use more frequent vaccination. However, analysis of the non-summarised data demonstrated that the real problem was due to inadequate number of villages vaccinated, so this money would have been wasted, and the correct response would be to increase the program to cover more villages.

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. farmers 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)

6. Determine the available budget for improving reporting

7. List possible interventions in order of size of benefit (expected increase in reporting rate)

8. 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 have 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 policies.

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 training (e.g. farmer schools, focus group discussions, etc.) with an emphasis on disease reporting. The advent of technology has helped. Some countries have a telephone hotline for farmers to report suspect cases. This information reaches the central veterinary services 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.

Others are using the SMS technology where farmers who can afford to have mobile phones send an SMS message to the veterinary services. 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.

Digital pens are another technology that can help improve reporting systems. These are pens with a miniature camera embedded in them. The field veterinary office completes a paper form, but the information on the form is captured by the pen, and then transmitted directly to a central computer via mobile phone.

Whatever approach is used, the basic objectives to increase the speed and efficiency of reporting are:
- Communication pathways
  ◊ Get information from field to decision makers
  ◊ Decision makers at multiple levels

- Get feedback back to field

- Speed of communication
  ◊ Emergency diseases – as rapid as possible
  ◊ Routine diseases – in time for appropriate decisions to be made

- Efficient and accurate
  ◊ No duplication
  ◊ Minimise transcription

- Suitable for analysis
  ◊ Disaggregated, original complete data
  ◊ Electronic
  ◊ Secure
  ◊ Verified

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 and 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 who 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.

Standardised data collection form

To encourage standardisation, 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:

1. Keep it as short as possible. Only include those items that are absolutely necessary. The longer a form is 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.
2. Make it quick to complete. Where possible, use tick-boxes to indicate responses, rather than writing out words in full.
3. 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.
4. Ensure that there is a field for comments, so that any unusual aspects can be explained
5. Don't limit possible diagnoses. Common diagnoses may be listed, but ensure that field staff can report other less common diagnoses.
6. Avoid duplication. Make sure that the staff don't have to write the same thing in different places or on different forms.

Key information to be collected

The exact information required will vary between countries, depending on the administrative system and the surveillance priorities. However, as a general guide, most passive disease report forms should capture the following information:

- Who
  - ◊ Name of livestock owner
  - ◊ Name of reporting officer

- Where
  - ◊ Location of animal
  - ◊ In text (address including village, district, province)
  - ◊ In coordinates (latitude and longitude)

- When
  - ◊ Date of examination
  - ◊ Date of onset of the problem

- Animals
  - ◊ Species / breed
  - ◊ Age
  - ◊ Gender
  - ◊ Production system
  - ◊ Numbers (importance of unambiguous definitions)

◊ Total number of animals in the group
◊ Number of animals affected by the disease
◊ Number of animals that have died of the disease

- Disease
  ◊ Signs or syndromic classification

- Diagnosis
  ◊ Presumptive diagnosis
  ◊ Nature (basis for diagnosis)
  ◊ Differential diagnosis

Example data collection forms are shown in Appendix 1.

Staff training in the use of the form is also important. 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 (smart 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. The computer can have a number of data quality checks programmed in, and require certain data to be submitted. For example, a disease report may not be submitted until the number of affected animals has been entered. Also, 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 too 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. For instance, the figure below illustrates the data reporting pathway for a typical veterinary service. Data is moved progressively through the administrative hierarchy. The next figure shows an alternative disease reporting system. In this example, data is entered into a central database over the internet by the district veterinarian. In addition, an SMS system allows direct submission
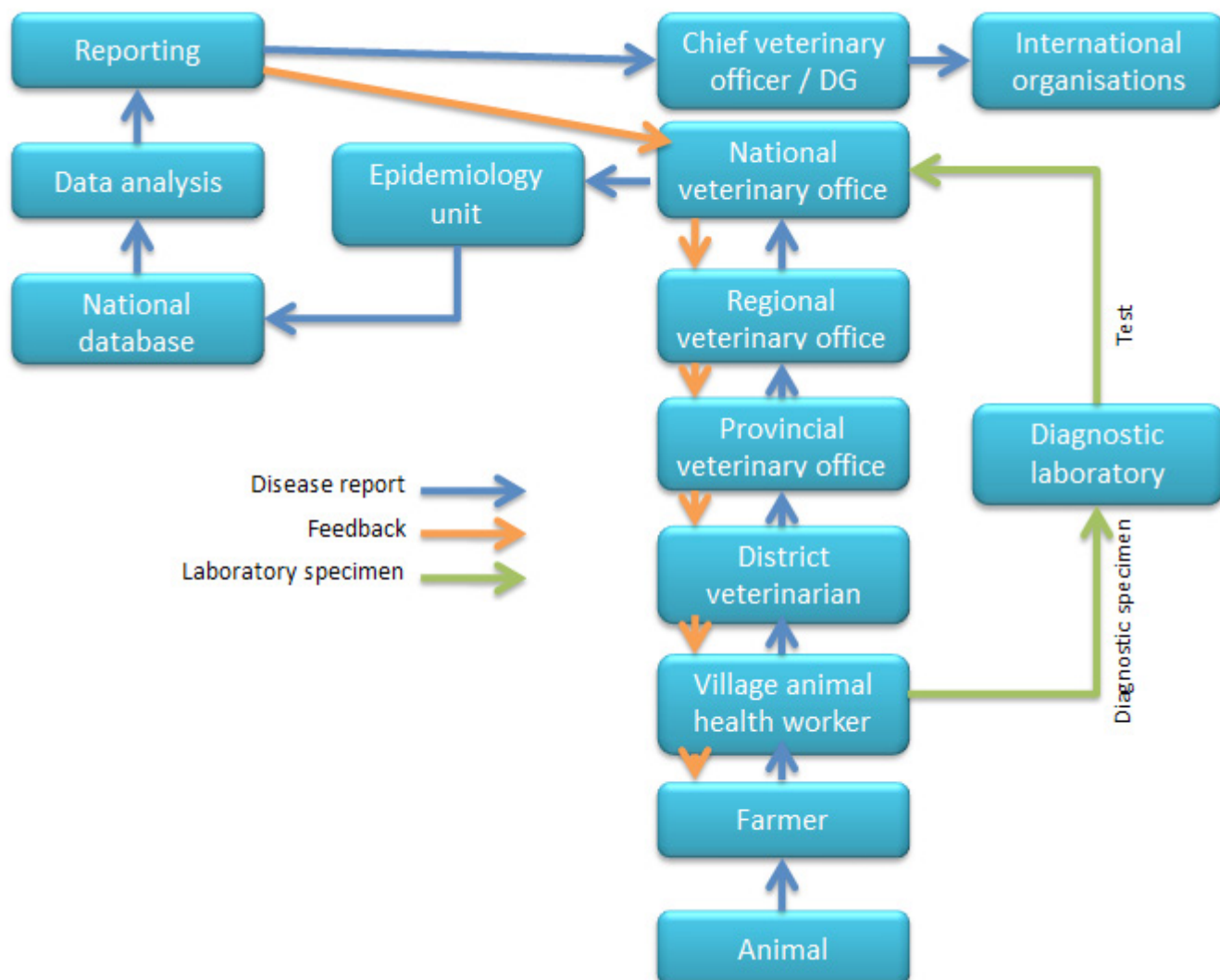
of emergency reports by farmers or village animal health workers. This data is automatically analysed and reported, so that it becomes immediately and simultaneously available to all who need it, including the other levels of the hierarchy (provincial and national offices).

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

Flowchart legend:
- Disease report →
- Feedback →
- Laboratory specimen →

Flowchart boxes: Automated reporting, Automated analysis, National database, Chief veterinary officer / DG, Epidemiology unit, International organisations, National veterinary office, Regional veterinary office, Provincial veterinary office, District veterinarian, Village animal health worker, Farmer, Animal, Diagnostic laboratory. Labels: Simultaneous reporting to all, Remote access via, Emergency SMS or telephone.

central office, the provincial offices should have immediate access to the data as soon as it is entered.

Disaggregated data
As described above, disaggregated (non-summarised) 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 livestock 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).

REPRESENTATIVE SURVEYS

A representative survey is used when it is important to measure the level of disease accurately (usually the prevalence of the disease). Examples of when you may need to use a representative survey include:

- Planning control programs: For example, when controlling or trying to eradicate brucellosis in cattle, it is common to start by vaccinating the entire population to reduce the prevalence. Then, when the prevalence is low enough, test-and-slaughter is used to eradicate the disease. Modelling has shown that it is best to switch from vaccination to test-and-slaughter when the prevalence is 2%. If the prevalence is higher, test-and-slaughter is very expensive because there are too many infected animals. If it is lower, eradication is delayed as vaccination alone cannot eliminate the infection. A survey is required to determine if the prevalence is above or below 2%.
- Monitoring a vaccination program: Normally the aim of a vaccination program is to achieve herd immunity – a level of immunity at which the disease will no longer spread. For most diseases this level is about 80%. To ensure that the vaccination program is working, surveillance is necessary to determine if this level of 80% has been achieved or not.
- Monitoring a control program. Disease control programs are often very expensive. In order to justify the continued expense, it is important to be confident that the program is working. Surveys can be used to repeatedly measure the level of disease and see if the prevalence is continually decreasing. If the prevalence increases during a control program, clearly something is not working.

There are various other reasons for conducting a representative survey. However, in each case, in order to answer the question being asked, it is important to be confident that the measure of prevalence is correct – which means that it is not biased. Representative surveys are the only way to confidently measure the level of disease without bias.

Quick guide

Implementing a representative survey can be complicated, and there are many different factors to be taken into account. The design of the survey, sampling approach, sample size and so on can be varied to meet the needs of the specific situation. It is therefore difficult to provide a general guide for all representative surveys.

However, a common situation is a representative survey designed to measure the level of disease (or the level of immunity achieved by vaccination) when there is little previous information. This section describes the steps required to implement a simple representative survey which can be practically implemented and used in many different situations. This is known as the "30 by 7" design, which involves sampling 30 farms or villages and 7 animals in each farm or village. This is a robust two stage sampling approach that allows the quick estimation of prevalence with reasonable accuracy (normally within +/- 10% of the true value).

1. Identify the purpose of the survey and the question that is being asked.
2. Identify the population of interest. Determine the first stage sampling unit (epidemiological unit). Normally this is either the village (when animals owned by different owners within a village have relatively close contact with each other, such as common grazing), or the farm (when animals are separated into distinct farms).
3. Obtain or generate a sampling frame. This is a list of all the villages or farms for the population of interest.
4. Take a random sample of 30 villages or farms, using the random number table at the end of this book.
5. Determine what information or specimens will be collected. For example, blood samples.
6. Set up field teams and train them.
7. Organise logistics including survey schedule, transport, specimen collection, restraint equipment and laboratory analysis requirements.
8. For each field visit, start with a meeting with the farmer or village livestock owners.
9. Build a list of all the animals on the farm, or the livestock owners and number of animals owned in the village.
10. Use this list for random sampling of individual animals.
11. Identify selected animals, restrain and collect samples.
12. Record essential information and store samples for transport.
13. Transport samples to laboratory for testing.
14. Enter test results and other field information into a computer.
15. Analyse the data to calculate the prevalence.

What are they good for?

Representative surveys are good for:
- Measuring the level of disease (prevalence or incidence) without bias (e.g. when evaluating if a vaccination program has achieved herd immunity or not).
- Comparing the level of disease between two geographical areas (e.g. when planning the establishment of a disease free zone or progressive disease control program).
- Comparing the level of disease over time (e.g. to assess progress in a disease control program).
- Comparing the level or impact of different diseases to determine the priorities of the veterinary services.

Representative surveys can also be used to demonstrate freedom from disease, but they are not as efficient as risk-based surveys.

What are they not good for?

Representative surveys are not good for:
- Early detection of new disease outbreaks. This is because the sample size of a survey is limited and they therefore have poor population coverage. Early detection requires high population coverage.
- Case finding as part of a disease control program. Case finding requires high population coverage as well.

Sampling frames

In random sampling, every unit of interest in the population has the same chance of being selected. In the techniques described above, this is achieved by using random numbers, and picking units of interest from a list. This list is called the sampling frame, and should contain every unit of interest in the population.

Example: A survey is conducted in a large intensive piggery to estimate the prevalence of pigs with respiratory disease. The farmer keeps a list of all mature sows and boars, each identified with an ear tag number, so this list is used as the sampling frame. Twenty animals are selected using random numbers from the sampling frame, and these animals are examined for signs of respiratory disease.

Clearly this survey has a problem with selection bias. It is not possible to infer the true prevalence in the piggery from the survey results, because the selection bias means that the sample is not representative of the population. The sampling frame does not include grower pigs, only mature breeding pigs. As respiratory problems are more common in growers than adults, we are likely to get misleading results, even though we used random sampling. This is because the sampling frame was incomplete, and did not include every animal.

A different problem can occur when a sampling frame lists the same units of interest more than once. In a village sampling frame, if one village is listed twice, then it has twice the chance of being picked than other villages. Another difficulty that can happen is the problem of identifying the elements from the list. Sometimes there may by two animals with the same ear-tag number, or two villages with the same name. The ideal sampling frame is therefore a list which:
- contains every unit of interest in the population (no omissions),
- contains every unit of interest only once (no duplications), and
- uniquely identifies every unit of interest.

Sometimes a suitable sampling frame already exists. When surveying villages, the government statistics office, and many other government departments usually maintain lists of villages, often computerised with unique identification numbers. These lists are very suitable for use as a sampling frame. The statistics office or agriculture department may also maintain information on livestock population, but to be useful, this needs to be up-to-date, and have the population of each village instead of summary figures for districts or provinces.

Sampling frames for farms may be harder to find. Registration records for commercial farms or farm supply companies (e.g. feed suppliers) may be able to provide information, but it is important to check how complete this is.

Any sampling frame is likely to be imperfect, either missing a few members of the population, or not identifying others properly. Just because a sampling frame isn't perfect, it doesn't mean it can't be used. It is a matter of

judgement to assess how good the sampling frame is, and whether the problems with it are likely to affect the results of the survey. For instance, if a sampling frame is missing 20% of the population, it may be better to try to find a better sampling frame. However, if there is no pattern as to which members are missing, then results from a survey using the frame could be perfectly adequate. On the other hand, even if only a small number are missing from the frame (say 5% or 10%), but there is a clear pattern (for instance all the biggest farms are missing), then there is a significant danger of the results being biased.

In many cases, no existing sampling frame is available. To carry out a survey using random sampling, it is then necessary to either:
- build a new sampling frame, by identifying all the units of interest in the population and creating a list;
- use a different sampling strategy that requires a different type of sampling frame which is easier to obtain (such as two-stage sampling, described on page 66), or
- use a specialised technique for random sampling with no sampling frame (random geographic coordinate sampling).

Field operations

A common problem encountered in livestock disease surveys in developing countries is deciding how to select a random sample of animals from within a village. In many countries, the smallholder village farming system is an important part of the livestock industries. One village usually has many livestock owners, each with varying numbers of animals. Often, these animals are in relatively close contact, either roaming unrestrained (e.g. village chickens) or housed or grazing together. Because of the close contact between animals belonging to different owners, it is easy for contagious diseases to spread through the village. Usually, from the point of view of a disease survey, all the animals in the village can be considered to belong to one large herd, even if they are owned by many different owners. All animals are generally exposed to the same diseases, and are reared using similar husbandry techniques.

When conducting livestock disease surveys of smallholder livestock raised in the village system, it is usually more sensible to treat them as a single herd, and to draw a simple random sample from the population of all animals in the village. This is difficult, as the animals are owned by many different people, and there is usually no sampling frame available. Even if figures on the village livestock population are recorded, these are usually only collected once per year, and are often too out of date to be of any use. In addition, animals are rarely individually identified (e.g. with ear tag numbers).

To overcome these problems, a practical technique for randomly selecting individual animals in the village is described below. To illustrate the technique we will use an example:

Example: A survey is conducted in a village to monitor the effectiveness of a Foot and Mouth Disease vaccination program. The aim is to estimate the prevalence of cattle and small ruminants in the village with antibodies against Foot and Mouth Disease. As all species are susceptible, and animals in the village are in close contact, all the cattle and small ruminants are treated as a single herd. The village has 48 households that raise either cattle or small ruminants or both. There are a total 49 sheep or goats and 125 cattle in the village for a total of 174 animals, and a random sample of 20 animals is required.

Building the sampling frame

Village interview

The first task is to build a sampling frame, listing and uniquely identifying every animal in the village. It is unlikely that any one person in the village would know exactly how many animals each of the 48 households had, and any records are likely to be out of date. One option is to walk around the village and either ask the owners, or count the animals directly (that is, conduct a census of animals in the village). Conducting a census is time consuming and it is easy to miss some animals, but it may be the best approach in some circumstances. Another approach that is sometimes useful is to hold a village interview, to which all the livestock owners are invited, and to ask them how many animals they have. A village interview with all the livestock owners requires some organisation, and may take a few hours to complete, but if this is possible, it is an efficient way to collect information for a sampling frame.

Village interviews are also extremely useful for collecting different types of information, as well as sharing information with farmers and answering their questions.

It is important to try to get as many of the village livestock owners as possible to attend the meeting, to make it easier to build a complete sampling frame. After explaining the purpose of the survey, each livestock owner present at the meeting is asked, in turn, what their name is and how many animals they keep. This information is recorded on a sheet with the columns shown below.

N°	Name	Cattle	Buffalo	Total	Cum. Total	Selected
1	Nkoroi	5	-	5		
2	Korok	2	3	5		
3	Khalil	-	4	4		
4	Fandamu	8	2	10		

When the information has been collected from each livestock owner present at the meeting, collect information about those livestock owners not present. The group is asked to identify all the owners who are not at the meeting, and to estimate how many animals they keep. This step may take some persistent questioning, and require prompts to help the owners think of others not at the meeting. Experience has shown that village interviews are usually able to make a list that contains almost every animal in the village.

Selecting the "number" of the animals
The list completed during the village interview serves as the sampling frame, but is different to the sampling frames discussed earlier. When drawing a random sample of animals, a sampling frame will usually be a list of all animals, with an identification number. In this case, the list is a list of all livestock owners (identified by name and a line number), with the number of animals kept. This list may be used as an animal sampling frame (rather than an owner sampling frame) because each animal in the village appears on it (although they are not yet individually identified – we will solve this problem later).

Random selection of animals
The list can now be used to randomly select animals using a random number table (see Appendix 2).
1. On the data recording sheet, calculate the cumulative total number of animals and write it in the column marked Cum. Total. The cumulative total is the total number of animals kept by all livestock owners in the village up to that point.

Example: The cumulative total for owner N° 1 is just the total number of animals, 5. The cumulative total after owner N° 2 is equal to the number of animals kept by owner N° 2 (5), plus the previous cumulative total (5), which equals 10. The cumulative total after owner N° 3 is 4 plus the previous cumulative total (10), or 14. This is continued to the last owner. Note that the last number is equal to the total number of animals in the village.

N°	Owner Name	Cattle	Buffalo	Total	Cum. Total	Random Number	Animal Selected
1	Nkoroi	5	-	5	5		
2	Korok	2	3	5	10		
3	Khalil	-	4	4	14		
4	Fandamu	8	2	10	24		

The numbers in the cumulative total column represent ID numbers for each animal in the village. Owner N° 1 has animals with ID number 1 to 5. Owner N° 2 has animals with ID numbers 6 to 10, and so on. These new animal ID numbers can now be used for random sampling.

N° 1 (Nkoroi)					N° 2 (Korok)					N° 3 (Khalil)				N° 4 (Fandamu)										
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

2. Using a random number table pick the first random number (see Appendix 2 for instructions on using a random number table to select random numbers). The random number must be between 1 and the total number of animals in the village, given by the last number in the cumulative total column. This number represents an animal that is to be selected. Find the owner of the animal on the list.

Example: In our example village, we need to pick a number between 1 and 174 (the total number of cattle and buffalo). If we picked the number 12, we need to identify which owner owns animal number 12. Search down the cumulative total column for the first number greater than 12, which is 14, at owner N° 3. This means that owner N° 3 is the owner of animal number 12.

3. Now that we have identified the owner, we need a way of identifying the individual animal. We need to calculate which animal in numeric order the selected animal is.

Example: We have selected animal number 12 belonging to owner N° 3. Owner N° 3 has 4 animals, and we need to decide which animal we want. The animals belonging to owner N° 3 would be numbered 11, 12, 13, and 14 if we had a true list of individual animals. If we want animal number 12, it is the second animal belonging to owner N° 3. A quick way to calculate this is to subtract the cumulative total for the previous owner from the random number selected. In this case, we would take 10 (the cumulative total for owner N° 2) from 12 (our random number) to give 2. This means that we want the second animal belonging to N° 3.

4. Record the number of the animal next to the owner in the Selected column. Then repeat steps 2 and 3, selecting more random numbers from the random number table and finding the animal in the same way. Continue until enough animals have been selected. If the same animal is selected twice, discard that random number and pick a new one. This is because we always use sampling without replacement when selecting animals. It is possible to pick several animals belonging to the same owner.

Example: Three more random numbers are selected: 17, 3 and 20. The animals have been selected and recorded on the sheet below. Check for yourself to see how it was done.

N°	Owner Name	Cattle	Buffalo	Total	Cum. Total	Random Number	Animal Selected
1	Nkoroi	5	-	5	5	3	3
2	Korok	2	3	5	10		
3	Khalil	-	4	4	14	12	2
4	Fandamu	8	2	10	24	17, 20	3, 6

Identifying selected animals
Regardless of which method is used to randomly select animals, the result will be a list of owners and animal numbers that looks like this:

    Owner 1   Animal 3
    Owner 3   Animal 2
    Owner 4   Animals 3, 6
    Owner 8   Animal 7
    Owner 11   Animals 2, 9, 16
    Owner 22   Animal 2

The approach to identifying which individual animals should be included in the sample based on these numbers is as follows:
1. Identify the owners of the selected animals. If selection was done manually using a random number table, the owners' names are already written on the list. If selection was done using a computer, it is necessary to copy the information back onto the data collection sheet, using the owner number to identify the correct owner.
2. Random selection can take place during the village interview. At the end of the village interview, all selected owners should be asked for their permission to allow the survey team to examine or collect specimens from their animals. Selected owners should be told that all the animals will have to be seen,

even if only one or two are required for examination.

3. For each owner, visit the place where their animals are kept. Look at the animals first without disturbing them.

4. Ask the owner to count, out loud, all of the animals. In this way, the owner is assigning a temporary identification number to each animal. Check on the list for which animal or animals are required, and note which ones are assigned the relevant numbers.

Example: Using the list shown above, for owner 4, animals number 3 and 6 are required. On visiting the place where the animals are kept, there are 8 cattle and 2 buffaloes. The owner starts counting the animals out loud, starting with the buffaloes as 1 and 2, then the cattle. The first of the cattle counted is number 3, which is one of the animals required. As counting continues, another of the cattle is given the number 6, which is also required. When the owner has finished, they are asked to catch the two cattle given numbers 3 and 6 for examination or specimen collection.

5. The process is repeated for each of the selected owners until all animals have been examined.

The technique is able to be used in a wide variety of situations, though some modification may sometimes be necessary. It may seem complex initially, but with good planning, and good communication with farmers it is simple to carry out. A few points need special attention.

• It should be explained to the owner that the survey team needs to look at the animals before capturing any. This is to avoid the problem of the owner selecting and capturing animals before the survey team arrives, thereby invalidating the random sample.

• Anybody can count the animals to assign numbers, including a member of the survey team, but it is very important that the person counting doesn't know which numbers are to be included in the sample. If they know, they could (consciously or subconsciously) select animals which are easier to restrain.

• Sometimes livestock owners keep their animals in separate groups, rather than all in the one place. Before visiting the animals, ask the owner how many animals are in each group. The groups can then be assigned ranges of numbers to help decide which needs to be visited.

Example: Survey staff talk with a cattle owner before visiting her animals. She says that she keeps 24 animals in three groups. The first group of 7 animals are kept a short way from the village. This group is assigned numbers 1 to 7. The second group of 12 animals is kept at the owner's house in the village. These are assigned numbers 8 to 19. The other animals are at her brother's house. These are given numbers 20 to 24. If animal number 14 is required, then only the group containing that animal (the ones at the house) need be visited. These are counted, starting at number 8. When using this system, it is important that the person assigning numbers to the groups does not know which animals are to be selected.

• Sometimes animals cannot be examined or specimens collected. This may be because they are unable to be captured, restraint equipment fails and they escape, they are too far from the village to reach, or the animal is agitated and dangerous to restrain. In these situations, a different animal will have to be substituted. When an animal is replaced, the sample is no longer completely random, because the chance of the replaced animal being in the sample is zero. This should therefore be avoided whenever possible. However, for practical reasons some animals may need to be replaced. When selecting a new animal, the same procedure as that described above should be used, using either a random number table or a computer. It is better not to just pick another animal belonging to the same owner.

Conclusions

The design of a representative survey described in this chapter provides just one simple example. There is an enormous range of different representative survey designs which can be customised to meet the needs of specific situations. The most common surveys involve two stages of sampling (e.g. farm or village, then animal) but other designs are possible in different circumstances. The task of designing a representative survey, setting up a sampling plan, calculating the appropriate sample size and analysing the data to ensure that there is no bias is complicated and normally requires the assistance of a statistician or epidemiologist. The book Survey Toolbox (available at http://www.ausvet.com.au) provides much more detail on the design, implementation and analysis of representative surveys.

RISK-BASED SURVEYS

Quick guide
Risk-based surveys are generally a more efficient way to demonstrate freedom from disease than representative surveys. This is because, by focusing on populations that have a higher risk of being infected (if the disease were present), the survey can achieve a higher sensitivity (probability of detecting the disease) with a lower sample size.

It is important to remember that risk-based surveys are best used when demonstrating freedom from disease. They are purposely biased towards populations at high risk, and if you use this approach when measuring disease prevalence, the result will be wrong.

The basic steps in running a risk-based survey to demonstrate freedom from disease are:
1. Identify the purpose of the survey and the question that is being asked.
2. Identify the population of interest.
3. Identify important risk factors for the disease. These are factors that can be used to divide the population into two or more groups, each with different risk of being infected. Risk factors may be at the herd level (e.g. herds that regularly import animals), or at the animal level (e.g. older animals).
4. Select the most important risk factor.
5. Estimate the strength of the risk factor in terms of relative risk. This is a measure of how much more likely animals in the high risk group are to be diseased than animals in the low risk group.
6. Estimate what proportion of the population is in the high risk group and what proportion is in the low risk group.
7. Determine the desired sensitivity of your survey. This is normally 95% (to be reasonably confident that the population is free from disease) or 99% (to be very confident).
8. Determine the design prevalence values at the herd and animal level. The herd level design prevalence is normally between 1% and 0.1%, and is often based on international standards or trading partner requirements. If in doubt, use 1%. The animal level design prevalence depends on the nature of the disease. For rapidly spreading epidemic diseases, use a value of 10%. For slow moving diseases, use a value of 1%.
9. Calculate the risk-based sample size using the on-line calculator at http://epitools.ausvet.com.au/content. php?page= RiskBasedSSComplex2Stage to calculate the number of herds/villages and the number of animals in each herd or village to sample. See the example below for more details on using this tool.
10. Use the same random selection and field surveillance approach as previously described in the representative survey chapter, except only select herds/animals from the high risk groups. For example
a. Make a sampling frame of the high risk herds or villages
b. Randomly select the required number of herds or villages from this high-risk sampling frame.
c. In each herd/village, make a sampling frame of all the high-risk animals.
d. Randomly select from these high risk animals.

11. Collect samples and perform laboratory tests
12. If any initial tests are positive, check the test results to confirm that they are really positive. If they are agreed to be true positives, the disease is present and it is not possible to demonstrate freedom from disease. You can only continue if all results are finally agreed to be negative.
13. Use the tool at http://epitools.ausvet.com.au/content.php?page= RiskBasedSeComplex2Stage to estimate the sensitivity of the surveillance and the probability of freedom.

What are they good for?
Risk-based surveys are good for:
- Demonstration of freedom from infection or disease. Risk-based surveys are more efficient than representative surveys.
- Demonstration of freedom from subclinical diseases or diseases with clinical signs that are subtle or easily mistaken for common or less important diseases. The famer passive reporting system can be a useful and efficient tool for demonstrating freedom from disease or infection, but only with diseases that have a good chance of being reported by farmers. For those diseases that are unlikely to be reported, risk-based surveys are the best tool to demonstrate freedom from disease.

What are they not good for?

Risk-based surveys are not good for:

- Measuring the level (prevalence or incidence) of disease, because they are biased towards the population that is most likely to be infected.
- Early detection of new or exotic disease, as the coverage is generally too low. However, risk-based approaches can be used to improve the operation of the passive farmer reporting system for high-risk population. For instance, while all farmers are expected to report disease outbreaks, extra effort could be made to increase awareness of those farmers in high-risk areas.
- Case detection, as the coverage is too low. Again, risk-based approaches can be used to improve case-finding through passive farmer reporting systems.

Identification of risk factors

An important aspect of risk-based surveillance is the reliable identification and quantification of risk factors. A risk factor is a factor that can be used to divide the population into two or more groups with animals (or farms, villages, etc.) in each group having a different probability of having the disease (if it were present). For example, one source of infection with highly pathogenic avian influenza (HPAI) is thought to be in contact with wild migratory birds, which tend to gather around water bodies (lakes and marshes). Domestic bird populations that have contact with wild birds and are near lakes or marshes are therefore considered to be at higher risk of becoming infected with HPAI than domestic birds that are not near water bodies. In the case of HPAI, there may be a number of other risk factors, including species (some species of birds are more susceptible to becoming infected than others), or contact with birds imported from countries known to be infected.

Note that the risk factor needs to be associated with the disease, but doesn't need to cause the disease. In our above example, being near water bodies is a risk factor, because it can be thought of as an (indirect) cause of the disease. Another risk factor could be farms that have recorded high mortality. Those farms with high mortality are more likely to have HPAI than farms with very low mortality. However the mortality is not a cause of HPAI – rather HPAI causes the mortality. This doesn't matter in the selection of a risk factor. All we need to know is that farms with high mortality are more likely to have HPAI than farms with low mortality.

Once risk factors have been identified, it is important to determine how important the risk factors are. For some risk factors, the difference in risk between the two groups may be relatively small (i.e. the factor is associated with only a slight increase in risk), while for others it may be large. The difference in risk between two groups is described using the relative risk (otherwise known as the risk ratio). This is the risk in the high risk group (often measured in terms of prevalence if the disease were present), divided by the risk in the low risk group.

For example, if HPAI were present in the population, there is a chance that different flocks could be infected in different parts of the country. However, data from previous outbreaks may indicate that the prevalence of infected villages near water bodies was 2%, while the prevalence of infected villages that were not near water bodies was 0.5%. The relative risk of infection is 2% / 0.5% = 4. This means that the risk of infection in villages near water bodies is four times greater than the risk in areas that are not near water bodies. Where historical outbreak data is available, this calculation can be easily made. However, in many cases such data is not available, and estimates from other countries or expert opinion must be used to estimate the relative risk for different risk factors.

Conclusion

Risk-based surveys can offer a more efficient approach to surveillance which aims to demonstrate freedom from disease. These surveys require a good understanding of the behaviour of the disease in the population (identification and quantification of risk factors). Compared to a representative survey, they are more efficient. However, passive farmer reporting is also able to provide evidence for freedom from disease (for those diseases that have clear clinical signs) and are generally much cheaper. Risk-based surveys should therefore only be used when there is an important requirement for good evidence of freedom from infection (e.g. trading partner requirements), and where there are no cheaper alternatives (e.g. when the disease may be subclinical so passive reporting of clinical disease is inadequate).

PART 3:
OTHER APPROACHES TO SURVEILLANCE

While farmer reporting, representative and risk-based surveys are able to provide most of the basic tools required for effective surveillance, there are many other approaches to surveillance which may, in certain situations, provide a more efficient means of collecting specific information. This section briefly describes a few of the common alternative approaches in common use:

- Sentinel surveillance
- Aggregation points (abattoirs, markets, watering points, dip tanks)
- Negative/Zero reporting
- Syndromic surveillance

SENTINEL SURVEILLANCE

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 is 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 and 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 or fomites. Such diseases can spread over great distances rapidly through the movement of live animals, and 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. 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 likelihood of detection.

How to improve
Sentinel systems can work more effectively if you:
* 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 seronegative animals can be brought into the herd to replace any animals that have seroconverted.

AGGREGATION POINTS (ABATTOIRS, MARKETS, WATERING POINTS, DIP TANKS)

Abattoir surveillance and surveillance at other aggregation points is commonly used as a form of either active or passive surveillance. This section deals primarily with abattoir surveillance, as animal inspection is normally carried out for public health reasons, providing potentially valuable passive animal disease surveillance data. Other animal aggregation points such as markets or dip tanks act as convenient and practical sites for active surveillance. Instead of conducting a representative survey, examination and specimen collection can be done at the one location. This makes the surveillance faster and less expensive, but the population under surveillance is no longer completely representative of the overall population. Any possible biases must be taken into consideration when interpreting the results.

Abattoir surveillance

The primary advantages of abattoir surveillance 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 or killing slabs 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 the animals 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. For example, if whole livers are used for sale, the abattoir may be reluctant to allow samples to be 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
The advantages of abattoir surveillance include:
- High coverage.
- Skilled observers, better able to detect clinical and pathological changes than livestock owners.

The main disadvantage is bias. The abattoir population tends to be younger and healthier than the rest of the population representing an important bias. As a result, abattoir surveillance may be used for:
- early detection
- demonstration of freedom from disease
- description of the level or distribution of existing diseases, and
- monitoring progress with control programs.

However, in each case the problems of bias need to be balanced against the advantages of low cost, better sensitivity and reasonably high coverage.

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.

However, 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 abattoir 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 and 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. In this case, supplemental information is 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. Often 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 – origin of the animal
There are different classifications of abattoirs. For example, there may be:
- 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 abattoirs that service a metropolitan city. In this case the animal origin can often only be traced to the last province where the animals were last sourced.

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 and time taken on each carcass. Providing extra training to meat inspectors to

help them identify priority diseases will increase the sensitivity of the system. The 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 than doing a detailed examination of every animal.

Accessing associated data
There are two approaches to improving the collection of data describing the animal:
- maximise the data that can be collected from the carcass
- 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, and 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 are 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 introduced 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, as 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 explored. 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.

NEGATIVE/ZERO REPORTING

A negative reporting or zero 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 of freedom. 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.

In many cases, 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.

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, for example with diseases that are difficult or impossible to detect from a distance, or 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 reporting form that is short, simple and quick to complete, so that veterinary staff do not have a

significant extra task. For example, a simple SMS message identifying location and date of visit may be all that is required.

- ensure efficient processing of the report forms, and data entry into a centralised database. This too can be automated with SMS messaging.
- 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.

SYNDROMIC SURVEILLANCE

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, including the normal level of disease, any seasonal variations and any normal random variations. This makes it easier to spot a change in this pattern when the new disease appears.

The data for syndromic surveillance systems should normally be fast, simple and cheap to obtain, allowing 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 clinical 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. These are those signs that are not observed directly in sick animals, but are observed indirectly, such as feed consumption, drug usage etc. This is sometimes referred to as indirect surveillance.

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 searching for 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. Other problems include:

- 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
- The 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 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.

PART 4:
DESIGN AND EVALUATION OF NATIONAL SURVEILLANCE SYSTEMS

DESIGN OF A NATIONAL SURVEILLANCE SYSTEM

Most countries have a range of surveillance activities that have been in place for many years. The overall surveillance system, made up a number of different components to address various diseases and priorities, has evolved gradually, according to changing needs and resources.

In a few cases, often due to civil unrest, existing surveillance (and other veterinary structures) have been destroyed, and there is a need to develop a completely new surveillance system.

Whether one is examining an existing system, or creating a new system, one is faced with a fundamental question: given the amount of resources that are available, how should they be distributed to achieve the best surveillance result? There is no simple answer to this question – it depends on a range of factors that are different between each country, including what diseases are present, trading opportunities, disease control programs, and regulatory and social constraints.

While there is no one simple best answer, this chapter describes a process that can be used to help make decisions about the appropriate blend of surveillance. In a country where a new surveillance system is being developed because little or nothing currently exists, this process can be used to identify those components of surveillance that will provide the greatest benefit using the available resources.

In countries with existing complex surveillance already in place, this process can also be valuable. For instance, it is often hard to decide to remove an existing component of a surveillance system. Politically, announcing new activities is usually popular, but cutting existing activities is much harder. However, due to changes in the disease situation, or developments of new more efficient approaches to surveillance, some existing activities may be unnecessary or inefficient. Using the procedure described here will help identify if the objectives of the inefficient surveillance can be met in other ways, and provide an argument for stopping it.

Overview
The approach is conceptually simple, but may require considerable effort to fully implement.
1. The first part of the process is to understand what needs to be done, and what resources are available to achieve this. The specific questions are:
a. What are the current surveillance priorities?
b. What resources are available for surveillance?
c. What are the options? What possible approaches are available to implement surveillance for different diseases or purposes?
d. What are the legislative or regulatory constraints? Are there any surveillance activities that must be used, even if they are less efficient than other options?
2. The second part involves progressively adding new surveillance activities to the overall surveillance mix and assessing the system after each addition:
a. Add a new surveillance approach. Start with the approaches that are least expensive, and make the greatest contribution to the surveillance objectives.
b. Assess how well the current combination of surveillance activities meets the defined objectives
c. Assess what resources are still available
d. Identify the highest priority surveillance objective that has been least well addressed
e. Select the least expensive and most effective tool available to address this objective
f. Continue the cycle until all objectives have been adequately met, or there are no resources left.

Step-by-step
While the approach appears simple and intuitive, it may be complex to implement. This is because, at each iteration of the procedure, it is necessary to evaluate the resources required, and the degree to which objectives are met. Both questions are complex and need careful consideration. This section provides a more detailed step-by-step guide to designing a surveillance system with optimal use of available resources.

Part 1: needs, resources and constraints
Surveillance priorities
The first task is to clearly and comprehensively define and quantify the different national surveillance priorities.

This is often difficult, but essential to provide the appropriate weight to different activities.

Normally, there will be a wide range of priorities, some general and some very specific.
1. List all the different objectives of surveillance. Select the priorities for your surveillance program from the list below. There may be other important activities that are not listed, so just add them to the list.
- Early detection of unknown diseases
- Early detection of known exotic diseases
    ◊ List diseases
        - Disease name
        - Clinically apparent
        - Carrier/subclinical state
        - Demonstration of freedom from specific diseases

    ◊ One-off demonstration of freedom
        - Disease name
        - Clinically apparent
        - Carrier/subclinical state

    ◊ Ongoing demonstration of freedom
        - Disease name
        - Clinically apparent
        - Carrier/subclinical state

- Identifying those diseases that are present (prioritisation, OIE reporting)
- Detecting if there appear to be changes in the level or distribution of disease (approximate measurements by space and time)
- Measuring the level of disease
    ◊ Disease control programs (monitoring progress)
        - List diseases

    ◊ One-off estimation of prevalence
        - List diseases

- Case finding
    ◊ List disease control programs

2. Assign a relative priority to each objective.
One practical interactive way of achieving this is to use a tool from participatory approaches: proportional piling. This exercise can be repeated with a number of independent stakeholders, or done with a single stakeholder group, seeking consensus.
a. Provide the stakeholders with a fixed number of tokens (e.g. 100). Inform them that these tokens represent money, or the importance of each surveillance objective.
b. Ask the participants to distribute the tokens amongst the different objectives that they listed in the first step. This provides a measure of the relative importance of each objective.

Surveillance resources
The next step involves defining what resources are available to spend on surveillance. It is essential to understand available resources so they can be allocated in the most effective way. Resources that should be listed include:
- Budget
- Staff with skills at different levels
- Laboratories
- Transport
- Information management

Surveillance options

Our priority list identifies what objectives we want to achieve. The resources list determines what we have available to achieve these objectives. The next stop is to identify how we might be able to achieve these objectives.

1. Develop a list of the different approaches to surveillance that could be used, as well as modifications to the main approaches.

This involves considering each objective, and listing a range of different approaches that might contribute to meeting that objective. Some approaches may be very effective at meeting the objective, but require a large number of resources. Others may only partly meet the objective, but require few resources.

It is also useful to identify options or sub-components for surveillance activities. For instance, a basic passive farmer disease reporting system may be one common surveillance approach. However, these systems often suffer from problems with underreporting, making them less useful. A sub-component may be a farmer extension program to increase awareness about farmer reporting. This can improve the quality of the system, but requires further resources. Implementing a comprehensive feedback system may also improve the system by increasing data quality from participants in the system, but this also requires further resources. Treating each of these activities as a separate component will allow you to evaluate the cost (in terms of resources) and the benefit (in terms of achieving surveillance objectives) of different approaches as well as possible modifications or improvements to existing approaches. Examples of different surveillance approaches, improvements and modifications include:

*   Passive farmer reporting system
    ◊   Improvements
        -   Staff training
        -   Extension and publicity for increased awareness

    ◊   Modifications
        -   Negative (zero) reporting
        -   SMS / hotline
        -   PDS
        -   Syndromic (lay reporting)
        -   Sentinel practices

*   Existing data
    ◊   Indirect surveillance
    ◊   Syndromic surveillance

*   Active surveillance
    ◊   Structured survey
    ◊   Sentinel herds or flocks

2. Estimate the cost (in terms of different resources) required for each approach listed.
3. For active surveillance options determine how well it is able to meet particular objectives. This can be done in a qualitative or semi-quantitative manner. For instance, a qualitative scale might look like:

*   Does not contribute to the objective
*   Very poor
*   Poor
*   Moderate
*   Good
*   Very good
*   Perfectly meets the objective

A semi-quantitative equivalent would apply a number indicating the estimated percentage achievement of the objective, for instance, a surveillance activity may meet 80% of the objective.

Context and constraints

Identify any constraints to surveillance based on the following issues:
• Political
• Social
• Regulatory

For example,
• trading partners' import requirements may specify that a specified approach to surveillance must be used;
• international organisations such as the OIE may impose certain reporting requirements requiring specific surveillance;
• there may be political requirements to meet specific public concerns about animal diseases.

These may indicate necessary components of the surveillance system.

Part 2: Iteratively building a surveillance system

Once the required information has been gathered, we are ready to start building the surveillance system. This is an iterative process, meaning that one component or surveillance activity is added at a time, the cost and benefits of the system evaluated, and then the next component is chosen and added.

1. Start by adding the passive farmer reporting system (in its basic form without any modifications or improvements). This is virtually always an inexpensive system, and is capable of meeting a broad range of surveillance objectives. Every surveillance system should use this as part of the mix of surveillance activities.

2. Next add any other components that are required by political, regulatory or other constraints. These are components that you have no choice about, so they must be included.

3. Based on the components already added:

a. Calculate the resources required for each component, and deduct them from the available resources. This should be done separate for each resource type (financial, staff, laboratory, transport etc.). This will indicate what resources remain for further surveillance components.

b. Calculate to what degree each of the components meets the stated objectives of the surveillance. For instance, if one of the objectives is the early detection of clinically evident diseases, a passive farmer disease reporting system may be judged to meet that objective well, but not perfectly. However, if measuring the prevalence of brucellosis as part of an eradication program is another objective, the farmer reporting system may be assessed to meet that objective poorly, due to biased reporting and the inability to detect subclinical disease.

4. Identify remaining unmet priorities and resources

a. The remaining resources have been calculated in the previous step. These may be expressed in terms of financial resources remaining in the budget, number of staff person-hours available, number of laboratory tests still available, etc.

b. Calculation of the unmet priorities is more complicated and is best illustrated with an example:

Let us consider a simplified example in which there are 4 surveillance objectives. Each objective has been ranked to indicate its priority:

	Objective	Priority
1	Early detection of clinical exotic disease	10
2	CBPP case-finding	50
3	Measuring brucellosis prevalence	35
4	List diseases present in the country	5

A passive farmer disease reporting system is added first to the surveillance system. Its estimated ability to meet these different objectives is shown below in quantitative terms:

These figures indicate that the passive reporting system is judged to be very good for listing diseases that are present, as well as early detection, quite good for CBPP case finding (due to high coverage and clinical signs), but not good for brucellosis due to subclinical disease and biased reporting.

	Objective	% objective met
1	Early detection of clinical exotic disease	95%
2	CBPP case-finding	80%
3	Measuring brucellosis prevalence	5%
4	List diseases present in the country	100%

	Objective	Priority	Met	Remainder
1	Early detection of clinical exotic disease	10	95%	0.50
2	CBPP case-finding	50	80%	10.00
3	Measuring brucellosis prevalence	35	5%	33.25
4	List diseases present in the country	5	100%	0.00

The priority and the proportion of the objective that is met can be used to calculate the remaining unmet priority. Multiply the priority by one minus the proportion of the objective met to give the remaining priority, as shown below. For example, early detection has a priority of 10 and 95% of this objective is met by the passive surveillance system. 10 × (1-95%) = 0.5.

These calculations indicate that the passive system has met many of the priorities, but that measuring brucellosis prevalence (with a remaining unmet priority of 33.25) and CBPP case finding (with a remainder of 10) both still need to be addressed.

5. Identify the most important priority remaining. In our example above, this is measuring brucellosis prevalence (33.25).

6. Select the surveillance approach that can address it most effectively at least cost (and that is able to address the most other priorities). To measure brucellosis prevalence, an unbiased estimate is needed. This can be best achieved using a representative survey, but this will require significant resources. It may also be used to assist with CBPP case finding.

7. Add the selected new approach to the surveillance list

8. Recalculate the remaining priorities and resources. Calculation of the extra resources required for the new surveillance activity may be straight forward. Calculation of the new remaining unmet priority is done as illustrated above. However, it should be noted that some surveillance approaches are not independent, which means that if one meets 20% of the need, and another meets 30%, then they do not necessarily combine to meet 50%. A qualitative assessment is required of how much extra value is provided by the new surveillance, given that there are a number of existing surveillance activities.

The process continues, adding in new surveillance approaches and recalculating objectives and resources each time, until either the resources are completely used up (in which case some objectives may not be able to be fully met), or all the objectives are met (in which case some of the available resources may not be required).

Conclusion
This process attempts to provide a relatively objective approach to building an overall surveillance system, balancing surveillance priorities with available resources. While it attempts to be transparent and objective, some judgement is required about the degree to which different activities are able to meet different objectives. Also, the development of the list of different surveillance options will be more comprehensive if it is addressed with a certain amount of creativity.

As a result, the process may not produce exactly the same results when used by different groups. Nevertheless, it provides a structured framework to assist with decisions in surveillance design, and may, in many cases, reveal redundancy or gaps when applied to existing surveillance systems.

EVALUATING A SURVEILLANCE ACTIVITY

The information needs of a national veterinary service are constantly changing, due to a changing disease situation, or a changing trade or political environment. Once established, a surveillance system may successfully continue to generate information; however there is a risk that this information may no longer be the information required, or that the system no longer operates as efficiently as it might.

It is therefore useful to periodically evaluate surveillance activities. This evaluation attempts to describe and critically assess current surveillance, in order to improve the surveillance, ensure it meets international standards, or satisfies trading partner requirements.

Two main general approaches to evaluating surveillance have been used: quantitative and qualitative. In both approaches, a set of characteristics of the surveillance system are described and assessed. In quantitative evaluations, each characteristic is scored to indicate how good the surveillance system is relative to some ideal. In qualitative evaluations, no scores are used. Instead, text descriptions are used to evaluate each characteristic.

Both approaches are useful, but the qualitative approach will be used here, as it tends to provide more clues about how to improve a system.

Overview

An evaluation of a surveillance activity may range from a quick assessment and verbal presentation, to a formal process that may take several months and results in a detailed report. In this description, it is assumed that the evaluation will result in a written report. To make this easier, a report template is presented, indicating the possible structure of an evaluation report. This is intended to guide the team doing the evaluation and ensure that no important points are missed. However, the structure and content of the report may vary according to the purpose of the evaluation and the purpose of the surveillance.

The report will normally include the following major sections:

- Front matter
  ◊ Title page, institution, authors, contents
  ◊ Executive summary
  ◊ Summary of recommendations

- Objectives and context
  ◊ Why the evaluation is being done?
  ◊ What is the context for the surveillance?

- Description of the surveillance activity
  ◊ What is the surveillance and how does it work?

- Evaluation of the surveillance activity
  ◊ How good is the surveillance, judged against a range of characteristics?

- Conclusions and recommendations
- Appendices and references

Objectives and context

This section explains why the evaluation is being performed, what the surveillance is for, and the context in which the surveillance is being carried out.

Objective of the evaluation
The way in which a system is evaluated depends partly on why the evaluation is being done. This section describes the reason for undertaking the evaluation. Examples of possible objectives are shown below.

> **Possible objectives**
> - Review existing surveillance with the objective of evaluating its value and, if required improving or terminating the surveillance
> - Review surveillance systems in the context of international harmonisation, to identify weaknesses and aid the achievement of internationally acceptable standards
> - Allow an importing country to evaluate the reliability of surveillance data generated by an exporting country

The details of the evaluation will vary according to the objective. For instance, if the evaluation is being done by a trading partner in order to assess if disease status information generated from the surveillance system is reliable, the trading partner will be primarily interested in the quality and completeness of the surveillance, but is unlikely to be interested in whether it is being done cost-effectively.

Purpose(s) of the surveillance
While the previous section talked about why the current evaluation is being undertaken, this section explains why the surveillance itself is done. This may be described in terms of a general purpose, and a specific purpose. The **general purpose** is normally one or more of the following:

> **General purposes of surveillance**
> - Early detection of new, exotic or emerging diseases
> - Demonstration of freedom from disease
> - Measure the level of existing disease
> - Case finding

The **specific purpose** provides a more detailed explanation. For instance, if the general purpose includes measuring the level of existing disease, we need to understand why this is being done. It may be, for instance, to monitor a control program by checking if the level of disease is going down, or it could be to assist with prioritising allocation of the animal health budget by identifying the most important diseases. Case-finding may be part of a disease eradication program (e.g. finding animals or herds infected with brucellosis), or for public health reasons (surveillance to identify animals infected with Trichinella to avoid human infection).

It is often useful to express the specific purpose of surveillance in terms of the question or questions that the surveillance is intended to answer.

Context
This describes the situation or environment in which the surveillance is being undertaken. It normally includes the following sections:
- Nature of the animal populations under surveillance
- General description of the resources available
- Regulatory environment
- Stakeholders

Animal populations
Examples of descriptions of different possible animal populations are shown below.

> **Nature of populations**
> - Intensive, extensive, both, other
> - Domestic, wildlife
> - Terrestrial, aquatic
> - Sedentary, migratory, nomadic
> - Geographic definition (country, province, national park)

Resources
Specific information on the cost and benefits of surveillance are included in the evaluation. This section should simply describe broadly the resource constraints for the surveillance. For instance: is the country a

developed or developing country; are there adequate laboratory facilities, human resources, transportation infrastructure, financial resources etc.

Regulations
What are the key laws and regulations under which the surveillance is undertaken? There may be local and national laws and regulations which either require that surveillance is done, or in some cases, limit the way in which it is done. There may also be regional or trading partner agreements that have an impact on surveillance. All OIE member states have certain surveillance and reporting obligations as well.

Stakeholders
This section identifies the groups of people with an interest in the surveillance evaluation. These may be the target audience (for instance the decision makers to whom the evaluation report will be delivered), or data providers – those from whom information about the surveillance is obtained.

Description of the surveillance activity
This section provides a description of the surveillance, and may contain the following headings:
• Overview
• Disease
• Approach
• Stakeholders

Overview
This section provides an initial overview of the surveillance so that the reader quickly understands the general system. More details are provided in the following sections.

Disease
This section contains information about the disease(s) that are under surveillance. This should include the following information:

Disease focus
Is the surveillance targeted (designed to detect a single disease, e.g. an African Swine Fever serosurvey) or general (designed to be able to detect a range of diseases, e.g. participatory disease surveillance)

Disease type
Is the disease know or unknown. Targeted surveillance is for known diseases. However, one of the purposes of surveillance may be to detect new or emerging unknown diseases.

Disease name
If the surveillance is targeted, what disease is it aiming to detect? Most commonly, this will be related to a specific agent. However, some surveillance may have broader definitions of the target disease. For instance, syndromic surveillance may aim to detect pneumonia (which could be caused by a variety of different agents).

Disease status
What is the current status of the disease (present or absent)? The disease status is relative to the geographical extent of the surveillance (as defined in the section on surveillance context above). For instance, surveillance may be undertaken in a disease free zone (where the disease is absent), but the disease may be present in other parts of the country.

Disease occurrence
What is the pattern of occurrence of the disease? Options include:

Patterns of occurrence
• Endemic
• Sporadic
• Epidemic

- Exotic
- Emerging
- Re-emerging

Approach
What is the general approach to the surveillance? Options include:

Approaches to surveillance
- Passive farmer reporting system
- Sentinel veterinary practice
- Participatory disease surveillance
- Negative (zero) reporting
- SMS or telephone hotline reporting system
- Abattoir surveillance
- Market surveillance
- Diptank surveillance
- Checkpoint / quarantine / export station surveillance
- Sentinel herd / flock
- Syndromic (lay reporting)
- Syndromic (veterinary classification)
- Indirect surveillance
- Representative survey
- Risk-based survey

In addition to the general approach, the description should include the following items:

Origin of information
Is the surveillance active (designed and undertaken specifically for the purpose of animal health surveillance) or passive (the veterinary services do not initiate data collection – the data is generated for a different primary purpose but then used for surveillance). Note that there is sometimes blurring between these two categories. For instance, a farmer reporting system is normally considered to be passive. However, if farmers are obliged to make disease reports directly to the government, and the main reason for this is surveillance, then it could also be considered active.

Time factors
How is the surveillance conducted over time? It may be:

Timing of surveillance
- Ongoing (data is coming in all the time)
- Periodic (surveillance is conducted at regular intervals, e.g. annually)
- Ad hoc (done repeatedly on an as-needs basis)
- One-off (e.g. a single survey)

Stakeholders
This section identifies all the stakeholders in a surveillance system and describes their role. This is an important part of the evaluation and necessary to understand and possibly improve the operation of the system. Stakeholders may be identified as individuals (e.g. the Minister of Agriculture or the Chief Veterinary Officer) or as groups at different levels (e.g. farmers, village animal health workers, district or regional veterinary officers). For each stakeholder, their role identifies what they do within the surveillance system. Do they:
- Provide information by making field observations?
- Process and transmit surveillance information?
- Transform information (e.g. data entry from paper forms)?
- Use the surveillance information?

It is important to recognise that a single stakeholder or stakeholder group may have a variety of different

roles. For instance, farmers are both data providers (in a passive farmer reporting system) and surveillance data users (they need to know the results of disease surveillance in order to make decisions about the care of their animals, such as whether to vaccinate or not).

Evaluation of the surveillance activity

The previous section (description) was to describe what the surveillance is. This section aims to describe how good the surveillance is. This is done by evaluating the surveillance against a range of different characteristics. There are very many different characteristics that have been used to evaluate surveillance, and these are listed here for completeness. However, many are of limited importance and value. The most important characteristics (which should always be included in an evaluation) are highlighted with the symbol !!, while the others may be included if they appear to be useful but may be omitted otherwise.

For each characteristic, the evaluation should describe the surveillance system, and then provide a critical assessment. For instance, when considering the characteristic of timeliness, the evaluation should first describe what delays there are in getting surveillance data from the field to the decision makers, and then assess the impact or importance of this. Is it fast enough? If not, how important are the delays? Is this a major weakness with the system, or just something that it would be good to improve, if possible?

Theme		Evaluation characteristic
Surveillance objectives	!!	Relevance
		Consistency with disease situation
		Recognition of stakeholders needs
		Completeness, level of detail, adequate to guide and evaluate surveillance
Surveillance approach	!!	Appropriateness of chosen approach
		Standardisation and documentation of procedures
Population	!!	Target population (population of interest)
	!!	Study population (population under surveillance)
	!!	Unit of interest (animal, household, herd/flock etc)
	!!	Epidemiological unit
	!!	Coverage
	!!	Distribution
Sampling	!!	Selection method
	!!	Representativeness
Data and specimens	!!	Primary data
		Data type
	!!	Data source
		Standardisation of data collection tools
Tests	!!	Tests used in the surveillance systems
	!!	Case definition
	!!	Test sensitivity
	!!	Test specificity
		Practicality, availability and cost
	!!	Test decision tree to describe testing scheme and basis for definitive diagnosis
Data management and communication		Form of the primary data collected (paper, electronic, verbal)
	!!	Information flow diagram
	!!	Timeliness
	!!	Feedback systems
		Security

Theme		Evaluation characteristic
		Interoperability
Stakeholders		Awareness
		Ownership
	!!	Acceptability
	!!	Participation
		Feedback/communication/exchange systems
	!!	Utility/benefit
Quantitative measures of surveillance quality		Surveillance sensitivity
	!!	Surveillance negative predictive value
	!!	Bias and precision
	!!	Detection fraction
		Animal or group-level sensitivity and specificity
		Test positive predictive value
		Test negative predictive value
Cost and inputs	!!	Direct surveillance budget
		Indirect financial support
		Veterinary service resources
		Non government resources used
Utility, outputs and impact	!!	Outputs
	!!	Benefits
	!!	Impacts
	!!	Efficiency
		Effectiveness
Quality control		Surveillance monitoring system
Future operation		Flexibility
		Multiple utility
		Portability
		Robustness
		Resilience
		Stability
	!!	Sustainability
Summary evaluations	!!	Fitness for purpose
		Usefulness
		Simplicity
	!!	Practicality
		Cost-effectiveness
		Cost-benefit

Surveillance objectives
This section relates to the stated objectives of the surveillance activity. If the objectives are appropriate, they should help answer questions about the design of the system.

Relevance
Are the stated objectives still relevant? Have any changes occurred in relation to trade or regulations that decrease the relevance of the surveillance?

Consistency with disease situation
Has the disease situation changed? For instance, is the surveillance aiming to evaluate a control program,

when the disease has already been eradicated?

Recognition of stakeholders needs
Do the surveillance objectives take into account the needs of all stakeholders?

Completeness, level of detail, adequate to guide and evaluate surveillance
Are the objectives expressed in enough detail to be useful? Do they clearly express why the surveillance is being done and allow us to determine if the surveillance is meeting the objectives?

Surveillance approach
Appropriateness of chosen approach
Is the approach chosen appropriate for the surveillance objectives? Are there any other approaches that may be more suitable? For instance, representative surveys for the detection of rare diseases may not be the most appropriate tool, and risk-based sampling could be more appropriate in some situations.

Standardisation and documentation of procedures
Are the surveillance procedures documented in adequate detail? Do all participants in the surveillance system have a copy of the document, and do they understand it. Are systems adequately standardised to ensure that specimens and data received from different participants can be analysed and interpreted in the same way?

Population
Target population (population of interest)
What is the population of interest (the population about which the surveillance is designed to provide answers)? Is it clearly defined and is it appropriate?

Study population (population under surveillance)
What is the study population? If this is different from the target population, why is this so, and what are the implications? For instance, in abattoir surveillance for tuberculosis, the population of interest may be all cattle in the country, but the study population is all the cattle slaughtered at controlled abattoirs. How are these populations different, what biases may this introduce in the surveillance results, and how important are these biases?

Unit of interest (animal, household, herd/flock etc)
What is the unit of interest? This is the smallest unit in the population from which data is collected. When doing a serosurvey or using individual clinical case reports, the unit of interest is the animal. In, for example, rabies surveillance based on a household questionnaire, the unit is the household. In syndromic surveillance involving farmer reporting of daily chicken flock mortality figures, the flock is the unit of interest. Does the chosen unit of interest allow the surveillance to meet its objectives? For instance, if the unit of interest is the herd, but the objective is to measure animal-level prevalence, the surveillance is inappropriate to meet its objective.

Epidemiological unit
What is the epidemiological unit for the surveillance? The epidemiological unit defines a group of animals which are considered to share approximately the same disease risk. Different epidemiological units will have different risks. For example, when considering FMD in a village system, possible epidemiological units are the household, the village, or a group of villages. If animals from different households mix freely within the village, but do not mix with animals from a different village, then the village is the epidemiological unit. However, if there are grazing areas that are shared with a neighbouring village, then the two villages may be a single epidemiological unit.

Coverage
The coverage is defined as the proportion of the study population that is included in the surveillance. For instance, if a survey has a sample size of 2,000 animals, and is drawn from a population of 2 million then the coverage is 2,000/2,000,000 or 0.1%. High coverage is important for early detection and case-finding.

In some systems, the actual coverage achieved may be lower than the potential coverage. For instance, passive farmer disease reporting systems have a potential coverage of 100% (all animals in the population are observed by their owners). However, as some owners are unwilling or unable to report, the actual coverage may be somewhat lower. Any difference between the potential and actual coverage should be described and analysed.

Distribution
The distribution of surveillance data can be assessed with reference to space, time or other factors. The spatial distribution of surveillance indicates where surveillance data comes from, and which areas may be underrepresented. It is most easily described using a map, either showing points indicating where data has come from, or shaded colours indicating the relative amount of data from different areas.

Temporal distribution indicates the pattern of data collection over time, and may be illustrated using a bar chart with the number of surveillance reports per week or month.

Distribution can also be assessed relative to other factors, such as species, disease, age, sex, breed and production system.

Sampling
Sampling is used to select a group of animals (or other units of interest) from the population for study.

Selection method
How was the sample selected? Possible general approaches include:

> **Selection methods**
> - Census (selection of the entire population)
> - Random sampling (using a formal randomisation procedure)
> - Systematic sampling
> - Convenience sampling
> - Haphazard sampling
> - Risk-based sampling

Representativeness
Is the sample representative? Is it intended to be representative and if not, why not? Lack of representativeness can be measured using bias.

Data and specimens
Primary data
What is the primary data that is collected by the surveillance system? Options include:

> **Primary data**
> - Diagnoses
> - Signs or syndromes
> - Classifications (e.g. immune status)
> - Negative disease reports
> - Indirect indicators
> - Risk factors

Data source
What is the source of the data? Does the data come directly from the animal (blood or tissue samples, direct clinical observation), from the farmer (a disease report) or from other sources?

Standardisation of data collection tools
Are the tools used for data collection standardised and properly documented? For instance, is there a standard disease report form for passive surveillance? For serosurveillance, are there standards for the

collection, storage and transport of blood samples? Is there a standard data collection form for other data such as age, sex, breed and location?

Tests
(!!) Tests used in the surveillance systems
What tests are used in the surveillance system? Examples of possible tests include:

> ### Examples of different kinds of tests
> - Clinical examination
> - Laboratory tests
> - Post mortem examination
> - Meat inspection
> - Case definition

Test sensitivity
What is the sensitivity of the test or test system used? The sensitivity is the probability that a truly diseased animal will give a positive test result. Is the sensitivity known? How, where and when was the value calculated? Is there any uncertainty about the value? What is the possible impact of this uncertainty? Does the sensitivity vary between different animals? What are the factors associated with this varying sensitivity (e.g. age, stage of infection etc.)

Test specificity
This is the probability that a truly non-diseased animal will give a negative test result. The same issues as listed for sensitivity need to be considered.

Practicality, availability and cost
How practical is the test to perform? Does it require resources that are difficult to obtain? Where is the test able to be done? How much does the test cost?

Test decision tree
Decisions on a diagnosis may involve performing several tests. It is useful to draw a decision tree to indicate what tests are used, when, and what decisions are made on the basis of the test results. A decision tree will typically start with a screening test, and then have one or more confirmatory tests that are used if the screening test is positive.

Data management and communication
Form of the primary data collected
What is the form of the primary data collected? Examples include:

> ### Form of the primary data
> - Paper
> - Electronic
> - Verbal
> - Blood samples
> - Tissue specimens

Information flow diagram
This is an important part of the evaluation. A flow chart is used to describe the flow of information, starting in the field, usually with the animal, and passing through different reporting and data processing steps, then to data analysis, reporting the results and delivery of the results to decision makers and data providers (feedback systems). This diagram should be linked to the list of stakeholders and their roles. At each step of the flow chart, it is useful to indicate:
- Who is responsible for the information at that step?
- What they do with the information (report, transcribe, review, analyse, make decisions etc.)?
- How is the information passed to the next step (verbal person to person, phone, mail, SMS, internet)?

- What form is the information in (paper, electronic, tissue or blood sample)?

Timeliness
How long does it take the information to get from the field to the decision makers? What are the points that cause the greatest delays? How important is it to transmit the information quickly, and what are the implications of any problems with timeliness?

Feedback systems
What feedback systems are included in the surveillance system? Who is data provided to, and is the form of the data appropriate for their needs?

Security
Is the surveillance data managed securely? Who has access to it, and how could sensitive information be misused?

Interoperability
Is the information management system able to work effectively with other systems? For instance, is surveillance data able to be reported electronically to different organisations, when required?

Stakeholders
Awareness
Are the stakeholders aware of the disease and their role in the surveillance system?

Ownership
Do different stakeholders have a feeling of ownership of the surveillance system, or do they feel that it has been imposed on them?

Acceptability
Are the expected actions of different stakeholders in the system acceptable to them?

Participation
Do stakeholders participate adequately in the system? Failure to participate may be due to weaknesses in any of the three previous factors.

Feedback/communication/exchange systems
Are systems in place to provide feedback to stakeholders? Is there an opportunity for stakeholders to communicate and exchange ideas with others involved in the surveillance system?

Utility/benefit
How useful is the surveillance system to different stakeholders? What direct and indirect benefits do they get from their participation?

Quantitative measures of surveillance quality
There are a number of quantitative measures of the quality of surveillance available, depending on the purpose of the surveillance. These are important aspects of the evaluation, as they allow direct comparison to other systems and international standards.

Surveillance sensitivity
This is the sensitivity of the surveillance system (not the individual tests used). This only relevant for systems that aim to demonstrate freedom or systems for the early detection of disease outbreaks. Surveillance sensitivity is defined as the probability that the system will detect at least one positive animal, if the disease is present at a specified prevalence.

Surveillance negative predictive value
This is the probability that the population is free from disease, given that the surveillance system has detected

no cases of the disease. It is relevant for systems that aim to demonstrate freedom or systems for the early detection of disease outbreaks.

Bias and precision
These are quality measures for systems that aim to measure the level of disease. Bias is a measure of systematic error, and precision is a measure of random error.

Detection fraction
For case-finding surveillance, this indicates the proportion of cases in the population that are successfully detected by the surveillance system.

Animal or group-level sensitivity and specificity
For case-finding surveillance, this indicates the performance of the test system at the animal or group (e.g. herd) level.

Test positive predictive value
This is the probability that an animal with a positive test result is truly positive.

Test negative predictive value
This is the probability that an animal with a negative test result is truly negative.

Cost and inputs
Important summary measures of the surveillance system include the cost-effectiveness and the cost-benefit of the surveillance. In order to assess these, it is necessary to know what the cost of surveillance is. The cost of surveillance can be assessed in terms of financial costs (direct and indirect) as well as resource usage.

Direct surveillance budget
What budget is allocated specifically for the surveillance activity?

Indirect financial support
What other budget contributes to the surveillance, for instance, salaries for surveillance personnel.

Veterinary service resources
What resources within the veterinary services are used for the surveillance? The types for resources to be considered include:

> **Types or veterinary service resources**
> * Personnel
> * Laboratories
> * Transportation
> * Communication / information management

Non government resources
Identify what resources from outside the government veterinary services contribute to the surveillance. These may include producers and industry contributions, as well as private veterinarians.

Utility, outputs and impact
These form the other component of cost-benefit and cost-effectiveness analysis.

Outputs
What does the surveillance system actually produce? What are the major tangible outputs of the system? These may include regular published reports, emergency notifications to international organisations, farmer newsletters, or briefing notes to decision makers.

Benefits
What are the benefits of the surveillance system? For example, if it is used to demonstrate freedom for trade purposes, what is the value of the trade that is supported by the surveillance? If it is used to monitor a disease control program, how important is the control program and how does it contribute to its success?

Impacts
What is the impact of the surveillance system? For example, has it been able to open up new export markets? Has it been able to detect new diseases early enough to prevent spread?

Efficiency
How efficient is the system? Does the system achieve its objectives while using the smallest amount of resources possible?

Effectiveness
How effective is the system? Does it fully meet its objectives?

Quality control
Surveillance monitoring system
Does the surveillance system have an in-built monitoring system to assess the quality of the system and quickly identify problems? If so, how does this system work? For example, a monthly analysis of district or provincial reporting rates and timeliness can be used to identify areas of poor participation in the surveillance. Check systems may be used in the laboratory to detect cases where blood collection teams have collected multiple tubes from a single animal.

Future operation
These characteristics describe how the system may operate in the future under different challenges.

Flexibility
Is the system able to successfully operate despite changes in the context in which it is operating?

Multiple utility
Can the system be used for multiple different objectives?

Portability
Is the system able to be applied in different contexts (for instance, the same system for a different disease, or in a different country)?

Robustness
Are the results of the system reliable even if there are changes made to the system? For example, is there enough redundancy in the data of the system to allow the objectives to be achieved even if there is some data loss or some aspects of the system fail?

Resilience
Is the system able to recover from difficulties and continue to operate?

Stability
Is the system able to produce consistent results over time?

Sustainability
Is the system able to operate successfully into the future? This is a summary measure of all the previous ones (and the most important measure of future operation). Sustainability is related to the simplicity of the system, the way in which resources are provided, and the commitment of stakeholders.

Summary evaluations
These final characteristics provide summary evaluations of different aspects of the surveillance system. They

are based on the detailed evaluations in previous sections, and lead to the conclusions of the evaluation.

Fitness for purpose
Is the surveillance system fit for the purpose for which it was designed? Clearly, the outputs of the system need to be good enough to meet the objectives, but fitness for purpose also evaluates whether they are too good. For example, surveillance system that provides highly precise measures of the level of disease may be too expensive, if a less precise estimate is all that is needed to support decision makers.

Usefulness
How useful is the surveillance system? Are the outputs significantly contributing to the aims of the stakeholders?

Simplicity
How simple is the system? In general, simple systems will be less expensive and more sustainable. However, complex important surveillance questions may require a more complex system to provide good results.

Practicality
Is the system practical? Are the resources available to make the system work? Are participants being asked to perform tasks that are unreasonably difficult or complex?

Cost-effectiveness
This assesses the balance between the costs of the system and how effectively it meets it objectives. Standard methodologies are available for undertaking this type of analysis and are beyond the scope of this manual.

Cost-benefit
This assesses the balance between the cost and the benefit of the system. Again, well established methodologies exist but are beyond the scope of this manual.

Conclusions and recommendations
The final part of the evaluation is the most important. Based on all the assessments made for a range of different characteristics, what is the overall conclusion in regards to the operation of the system, and how can it be improved?

PART 5: APPENDICES

- Example farmer reporting forms
- Random number table

APPENDIX 1: FARMER REPORTING FORM

This appendix contains three example farmer reporting forms. The first two examples are taken from FAO's Manual on Livestock Disease Surveillance and Information Systems (Food and Agriculture Organisation of the United Nations, Rome, 1999), available on the web at:
http://www.fao.org/docrep/004/X3331E/X3331E02.htm#AppII

Example 1

Province/Region (4-letter code)		District (6-letter code)	

Locality		Grid Reference	Lat		Long	

Date	Year		Month		Day		Farmer name	

Disease/Diagnosis		Differential Diagnosis	

Nature of Diagnosis	Suspected		Clinical		Smear		PM		Laboratory	

SPECIES: (Bov/Ov/Cap etc)	
NUMBER Cases (total affected)	
NUMBER Dead	
NUMBER At Risk	

AFFECTED POPULATION (mark the correct word)

SEX	AGE	SYSTEM	
male	neonate	dairy	beef
female	juvenile	mixed	trad
castrate	subadult	intensive	
all	adult	extensive	
?	all	other	
	?	?	?

MEASURES ADOPTED		MAIN CLIN. SIGNS	MAIN PM LESIONS	EPIDEMIOLOGY
Treatment				(source, rate of spread, vectors, reservoirs, sporadic, continuous etc)
Vaccination				
Dip				
Quarantine				
Other				
None				

Details of reporting officer:

Surname, initials:		Position	VET		VET AUX/PARAVET	LAY	

Example 2
Background information

Date		Farming system	
Reporting Officer		Comments and relevant background information	

Geographic information

Region		District		Locality	

Species affected

Species affected (check)	Bovine	Ovine	Caprine	Porcine	Other (specify)

Numbers involved

No. Cases		No. Deaths	
No. at Risk		No. Examined	

Categories most affected

Age category (check)	neonate	juvenile	subadult	adult	all	unknown
Sex category (check)	male	female	neutered	both	unknown	

Signs and lesions observed

Clinical signs	
Post-mortem lesions	

Actions implemented

Treatments (list)				
Other (check)	Vaccination	Dip	Quarantine	Cordon
Samples sent to (name lab)				
Date of submission		Type of sample/s		

Details of Diagnosis

Tentative Diagnosis		Differential Diagnosis	

Basis for diagnosis (check)	Rumour	Clinical history	Clinical signs	Blood smear	Laboratory test

Example 3
This example comes from the Lao People's Democratic Republic.

Lao People's Democratic Republic
Peace Independence Democracy Unity Prosperity

LaoBase Animal Health Information System

DISEASE REPORT FORM

Report date / /

Report Number (Lab use only)

Part 1: Submission Information

Location	Reason	Form completed by	Disease reported by
Village District Province Owner Name Address	☐ Disease Report ☐ Diagnostic ☐ Surveillance ☐ Export ☐ Accreditation ☐ Research ☐ Regulatory ☐ Disease Control ☐ Eradication	Name Address ☐ District Officer ☐ Provincial Officer ☐ Central Officer ☐ VVW ☐ Owner ☐ Other	Name ☐ District Officer ☐ Provincial Officer ☐ Central Officer ☐ VVW ☐ Owner ☐ Other
Previous report ID			

Part 2: Animal Information

Species	Sex	Number of Animals
☐ Cattle ☐ Buffalo ☐ Pig ☐ Chicken ☐ Goat ☐ Sheep ☐ Horse ☐ Shrimp ☐ Fish ☐ Dog ☐ Cat	☐ Male ☐ Female ☐ Castrated male ☐ Speyed female ☐ Mixed ☐ Unknown Age ☐ Days ☐ Weeks ☐ Months ☐ Years	Sick Dead Total in Village History and clinical symptoms

Part 3: Specimen Information   Laboratory use only

Specimen No.	Lab tests	Test type	Test results	Pos	Neg	?
☐ Whole Blood ☐ Serum ☐ Faeces ☐ Fresh tissue ☐ Fixed tissue ☐ Swab	☐ Serology ☐ Bacteriology ☐ Histology ☐ Virology ☐ Parasitology ☐ Haematology					
		Final Diagnosis				

Figure 2.7: DSSN submission form (English translation).

APPENDIX 2:   RANDOM NUMBER TABLE FOR RANDOM SAMPLING

Random number tables are a convenient source of random numbers. An example of a random number table is shown below and a full table is given in Appendix D. There are sets of numbers grouped into 5. In the above example, 10 numbers were selected to pick 10 villages from a total of 75. The way to use a random number table to select random numbers is as follows:

1. Choose a starting point and direction. You can start at the top of the table, or you can start anywhere in the middle. You can go across a row, or down a column. In this example, we will start at the top left number, and move across.
2. Calculate the range for your random numbers. The numbers required in this example are between 1 and 75.
3. Determine which digits to use from the numbers. The maximum number we want is 75, which has two digits. We therefore only need two of the five digits in each random number. To use the numbers efficiently, we can "cut" them in half, and think of the first two digits (42) as the first number, and the third and fourth digits (53) as the second number. The last digit can be ignored.
4. Search through the table for numbers in the required range. Any number between 1 and 75 is counted as one of our random numbers. Any number over 75 is ignored. Continue searching until enough numbers have been found (ten in this example).

Example: Using the table below, the first number is 42. This is between 1 and 75, so it is accepted. The second number is 53, and is also accepted. The next digit (9) is ignored. Moving to the right to the next group, the next number is 77. This is greater than 75 so is ignored. The next number is 68, which is accepted as our third random number. The last digit (6) is ignored. Continuing in this way we get a fourth (66), a fifth (52), a sixth (27), discard the next (79), a seventh (02, or 2), and eighth (47), a ninth (57) and a tenth (05, or 5).

Random number table
42539 77686 66524 27792 02474 57058 61530 76108 49436
27030 88085 84744 32591 57804 54790 24545 73422 23337
50253 66592 66151 18506 04391 35824 35397 32031 67780
54127 25147 79021 54189 43708 08178 82187 72106 53795

When using a random number table, it is a good idea to circle the numbers you select, and to cross off those that you discard. This helps you remember which numbers you select, and prevents you from using the same numbers again. You should always use new random numbers when sampling in a survey.

42539 77686 66524 27792 02474 57058

Random number table

289254	340041	266371	254185	205071	820043	176357	907292
391548	660945	406246	234042	150346	323533	638396	459088
050462	030683	379925	886505	652343	644085	323012	156821
154231	622661	098992	308992	619317	391012	051052	556005
604154	648161	570064	080618	702472	704437	582494	169236
242389	642271	321178	362816	591922	440445	482361	076710
462908	212823	517748	460564	067851	459642	928067	143752
124985	745725	942217	936247	254206	057165	703303	551409
599013	928142	005378	078369	089653	779419	517263	396961
471582	658480	352245	056825	184233	415163	124935	665949
448215	240640	193519	788233	685458	031504	391910	787994
621005	671082	547403	660656	794838	668391	201774	622943
164989	495935	676977	929229	510214	843710	697880	225096
785315	402435	805515	681396	431445	433127	365203	476255
116055	229508	410477	468095	162772	966571	797702	018788

407784	579692	919456	990059	498152	209755	351731	589535
682408	538857	921461	219896	603421	940305	027124	241635
880040	098476	736079	950105	388338	811292	407602	908049
346457	441648	409480	537748	059128	493972	363428	646375
439525	891661	182060	951117	660632	197453	901083	609756
095101	358240	418369	563569	464436	774514	794183	148876
995586	345657	802458	434885	887001	639018	393912	208109
587914	288631	194639	678989	504186	975746	014882	707236
189575	191661	605262	329409	099260	615945	208049	996814
165576	228718	535042	504136	002279	334428	422781	305042
656040	223735	899584	910642	317179	499757	034202	038135
421628	925824	157844	003917	829834	864512	507813	865019
976297	787985	113531	426064	842155	037838	740180	715897
205107	607920	049882	133304	772046	610777	820668	711437
422215	718190	884061	026397	438644	467266	124315	520333
866758	921490	842651	471548	502607	799714	380179	354682
801404	209491	625747	812488	008090	738780	395779	935321
009137	872890	979084	788289	434321	597840	364519	902983
470048	994779	204586	565552	160763	990017	097074	545619
025147	545982	372953	090466	546325	070091	548368	722714
814392	160912	386231	786028	482917	179513	982930	294383
308892	368485	824684	325785	164380	141774	861021	754094
900077	721460	858476	239449	515370	450464	975964	179568
417027	323990	822138	614807	999296	339475	259995	470779
538655	075425	046437	172869	806353	503386	009989	469097
129207	518826	952668	568427	034462	521258	540441	896099
508033	342218	202110	998707	103618	481196	933682	167216
805976	601167	025833	597563	295084	173823	342320	241625
552433	424020	292739	164676	206134	453210	125713	154668
924653	971487	594107	459597	759577	679445	967227	270519
007205	802620	175978	250045	786162	229958	626575	803776
340897	008501	306318	579078	102868	081484	324910	400165
921175	007202	303435	785633	143649	369589	250211	421608
468708	069790	539839	598937	051814	851633	641760	482263
533468	337846	676093	440591	415819	494546	747294	206549
105122	057264	321944	110632	506968	672605	544970	798452
853673	599409	597551	273722	175537	752814	414393	969749
654605	373426	727408	112069	258059	984174	882162	689298
648674	050484	763498	051803	473118	518221	471819	546769
980798	142339	933865	114187	886295	793823	230549	754580
944248	566284	763167	565744	393962	144797	336822	896502
660776	432124	508708	787093	510154	490683	666498	443232
791342	184203	466379	204606	451906	096190	054573	600145
680647	992308	039294	018932	556140	829631	391776	296140
914546	860493	671164	166861	995243	223057	457272	707198
128016	924065	253232	724867	806737	290810	784702	985821
083407	824017	264412	857847	363498	536611	292592	140417

447732	177663	404028	811337	437281	821966	597451	668522
129711	142128	740645	089091	494489	597784	268147	706356
867800	521095	933428	697801	909704	892578	856910	074090
704130	479873	647665	908349	221064	828318	769860	840503
694749	371093	475254	825008	675769	341608	247508	034507
809293	258204	380174	635725	737963	649914	519083	852714
839809	829603	550644	972132	207355	375827	330752	916694
456290	213814	505669	391575	689091	337830	102376	338443
175322	270408	457591	227673	629916	215893	831871	832994
741077	925149	522307	081440	859344	244837	232351	035300
695259	584033	514180	217716	123259	130807	348078	257176
888821	618595	159115	428478	280732	848106	528858	683572
984290	513765	409710	602097	057927	281820	330025	123889
725448	066287	015050	734973	007741	169907	198348	392060
717553	458093	457068	987868	686631	443064	878358	467588
025555	854247	138627	019900	198999	011004	073067	290026
284751	952114	176503	924297	840986	350052	564658	412182
040165	594025	631444	028890	287897	956822	459077	816229

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