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Review

Proposed terms and concepts for describing and evaluating animal-health surveillance systems

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ABSTRACT

The information provided by animal-health surveillance helps to reduce the impact of animal diseases. The widespread movement of animals and their products around the world results in an increasing risk that disease will spread. There is, therefore, a need for exchange between countries of comparable information about disease incidence; the exchange must be based on a common understanding of surveillance approaches and how surveillance systems are designed and implemented. Establishing agreed-upon definitions of surveillance terms would be a first step in achieving this standardisation, and will enhance transparency and confidence. To this end, a workshop was held with the aim of agreeing upon key terms and concepts for animal-health surveillance. In this paper, we describe the methods used at the workshop and summarise the discussions. A complete list of all the proposed definitions including lists of characteristics that can be used to describe surveillance activities and attributes for evaluation of surveillance is available in the workshop report (available at http://www.defra.gov.uk/ahvla-en/disease-control/surveillance/icahs-workshop/). Some important issues were highlighted during these discussions; of particular note was the importance of economic efficiency as an evaluation attribute. Some remaining inconsistencies in the proposed use of terms are highlighted (including the definition of 'risk-based surveillance' and the use of the term 'event-based surveillance').

1. Introduction

Animal-health surveillance provides an essential component of the evidence required to protect animal-health, facilitate trade, and (ultimately) protect public health. Through early detection and informed response, surveillance reduces the impact of animal disease on animal production and welfare and on public health. Effective surveillance also ensures that confidence in the health status of animals moving between countries is maintained and ensures that trade barriers are justified. When trade is maintained, the impact of disease outbreaks on the economy is reduced. Many outbreaks have had huge impacts on the economy, including: bovine spongiform encephalopathy (BSE) (McDonald and Roberts, 1998; Nathanson et al., 1997; Wilesmith, 1994); foot-and-mouth disease (FMD)

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(Scott et al., 2004); classical swine fever (Elbers et al., 1999; Jalvingh et al., 1999); and bluetongue (Szmaragd et al., 2010; van Schaik et al., 2008; Velthuis et al., 2010; Saegerman et al., 2008). The frequent movement of animals and their products around the world means that there is an increasing risk that infection will spread. There is, therefore, a need for exchange between countries of comparable information about disease incidence; this exchange must be based on a global understanding of surveillance approaches.

Agreed-upon definitions of surveillance terms will contribute to enhancing transparency and facilitating the exchange of data. Stakeholders include national and international veterinary authorities, livestock-industry and farmer organisations, and those responsible for designing and carrying out surveillance. Agreement upon key terms should facilitate comparative evaluation of surveillance activities and the selection of effective and efficient surveillance approaches for different purposes and situations. If stakeholders understand the value of the data collected and the impact of surveillance on animal and human health, this should lead to improved design of surveillance activities, enhanced compliance with data collection, increased likelihood of investment, and (ultimately) an increased probability of achieving the overall goal of the surveillance. The provision of information about the purpose, methods and benefits of surveillance activities will be facilitated by the development of clear, agreed-upon definitions. This attempt to encourage the use of consistent terms in public- and animal-health will facilitate the communication required to allow the development of the "one health" approach (http://www.onehealthinitiative.com).

There have been important developments in the methods used for animal-health surveillance including: the development of risk-based methods (Stärk et al., 2006); the application of scenario trees to support claims about freedom from disease (Martin et al., 2007); and new methods for collecting and analysing data to enhance early detection (Gibbens et al., 2008; Hyder et al., 2011; Kosmider et al., 2011; Saegerman et al., 2012). New developments in surveillance have led to the introduction of new terms which have not always been consistent or distinct in application. This has caused confusion which impedes effective communication and interpretation of surveillance results.

We describe the methods used and summarise the discussions that took place during an international workshop held prior to the International Conference on Animal Health Surveillance (ICAHS) conference in 2011. The aim of this workshop was to agree upon terms for animal-health surveillance; the main outcome was a report which is available on the websites of the Animal Health and Veterinary Laboratories Agency (AHVLA: http://www.defra.gov.uk/ahvla-en/disease-control/surveillance/icahs-workshop/) and the ICAHS websites (ICAHS: http://www.animalhealthsurveillance.org/index.php?n=Main.TerminologyFinal). The workshop report includes the agreed-upon definitions of general animal-health surveillance terms. It also lists and defines characteristics that can be used to describe surveillance activities, and attributes that can be used to evaluate these activities. Our intention is that the report should act as a reference document so that those commissioning, designing, implementing, and contributing to animal-health surveillance can use consistent terms.

The workshop report includes a detailed description of the outcome of the workshop but does not describe the methods used or the discussions that allowed participants to agree upon these definitions. Our objectives for this article are, therefore, to:

- describe the methods used to develop the agreed-upon terms;
- summarise the main outcomes of the discussions;
- discuss the differences of opinion that were highlighted by this process and how these were resolved to reach agreement;
- highlight any remaining areas of uncertainty about the use of terms in animal-health surveillance which require further discussion.

2. Methods

A first version of the definitions discussed at this pre-ICAHS workshop was developed following a review of the terms currently used to describe animal-health and public-health surveillance. This included the definitions used by organisations such as Centers for Disease Control and Prevention (CDC-Atlanta: http://www.cdc.gov/) and the World Organisation for Animal Health (OIE: http://www.oie.int). A summary of general terms, description characteristics, and evaluation attributes was prepared for discussion at a previous workshop in Durban, South Africa in 2009. The main focus of that workshop was to discuss the selection of appropriate surveillance methods for different situations, but those brief discussions about surveillance terms highlighted the need for the consistent use of these terms. The terms agreed-upon following that workshop (Hoinville et al., 2009) were used as the basis for the definitions to be discussed at the second workshop (held prior to the ICAHS conference in Lyon, France in 2011). The workshop in Lyon focused entirely on the development of agreed-upon terms for animal-health surveillance. The organisation of the workshop was funded by the Department for Environment, Food and Rural Affairs (Defra) as part of a project (Delivering intelligent surveillance, ED1039) designed to support the implementation of the UK Veterinary Surveillance Strategy.

The intention was to gather a group of international experts in animal-health surveillance, including representatives from as many of the groups currently working on the development of surveillance methods as possible. We aimed to include experts with knowledge of different sectors, scientific disciplines and geographical locations – while limiting the number of participants to ensure that effective interaction was possible. Thirty-eight experts were invited to attend the workshop or (if unable to attend) to recommend colleagues who might do so. Twenty-nine participants representing 18 organisations in 11 different countries attended. These included participants working in different scientific disciplines (e.g. economists and statisticians), providing various types of expertise (e.g. industry liaison and wildlife ecology) and with experience of

working with different farmed species (including cattle, sheep, pigs, poultry and fish). However, the location and nature of the ICAHS conference meant that most participants were epidemiologists investigating livestock populations in Europe. Only one participant was based in a developing country although two other participants had experience of working in these areas.

The objectives of the workshop were to:

- discuss and clarify general surveillance terms, characteristics used to describe surveillance activities, and attributes used for evaluating surveillance activities;
- identify the most useful description characteristics and evaluation attributes;
- identify any inconsistencies in the way that these terms are currently used;
- discuss whether it is possible to overcome differences in the use of surveillance terms and develop an agreed-upon set of terms for describing and evaluating animal-health surveillance.

The workshop organiser (author LJH) circulated a summary of the proposed definitions to all workshop participants prior to the workshop; the summary was accompanied by a list of suggested issues for discussion. Three facilitators and three note takers were identified from the list of workshop attendees; these helpers were provided with additional information about the proposed definitions and issues for discussion. The workshop started with a short introductory presentation about the aims and issues for discussion. Participants were assigned to one of three sub-groups (ensuring that there was a range of expertise in each of the groups). The groups initially reviewed the list of description characteristics and evaluation attributes to determine whether there were any gaps and to identify the ten most useful characteristics and attributes. The groups then discussed each of the proposed definitions to identify any alterations required and any inconsistencies in how these terms were used. Each small group presented their results to the whole group and the proposed definitions were discussed and amended as required.

The outcome of the workshop was summarised in an initial draft report; this draft was circulated for comments to workshop participants, those who were invited but could not attend the workshop, and all attendants of ICAHS in May 2011. Comments were received from 18 people. Where it was not possible to reach agreement about a definition at the workshop, individuals with a particular interest in the relevant aspect were invited to participate in discussions by email or phone to reach agreement about definitions. A final draft of the report was prepared and circulated to those working in animal-health surveillance in a range of countries and fields of expertise and also to experts in public-health surveillance; the purpose of this step was to identify any discrepancies between the terms included in the report and the terms currently used in their country or field of expertise. Input at this stage was specifically sought from those disciplines and geographical areas which were not represented by workshop participants. Twenty-seven groups or individuals commented on the final draft of the report. The definitions agreed-upon at the workshop and in subsequent discussions are included in the final report (Hoinville, 2011) in which any remaining inconsistencies were highlighted.

3. Workshop outcomes: agreed-upon definitions and issues discussed

The discussions clarified the definitions of some of the well-established surveillance terms (e.g. 'surveillance', 'monitoring', 'sentinel surveillance', 'active surveillance', 'passive surveillance' and 'emerging disease'). Definitions have also been provided for some of the more recently introduced surveillance terms (e.g. 'syndromic surveillance', 'event-based surveillance' and 'participatory surveillance'). Some new terms were introduced during these discussions: 'early-warning surveillance', 'hazard-specific surveillance', 'enhanced passive surveillance', 'surveillance purpose', 'policy purpose', and the different components of 'risk-based surveillance'. It was agreed that the use of terms which have been used inconsistently (such as 'targeted surveillance') should be discouraged. Finally, the meanings of some of the terms used to evaluate surveillance activities were clarified (including the related terms 'representativeness', 'coverage' and 'bias'; the different types of 'surveillance sensitivity'; and the different measures of 'economic efficiency'). Details of the discussions about the definitions that differ from those used previously, about which opinions differed, or that required further discussion are described in the following sections.

3.1. Definitions of surveillance and monitoring

The definition of 'surveillance' (Table 1) developed during these discussions is consistent with other definitions of health-related surveillance (German et al., 2001; OIE, 2012) in that it requires continuous or repeated measurement, provides descriptive information and is linked with action to mitigate risk. These characteristics distinguish surveillance activities from other related and complementary activities (such as "one-off" surveys or analytical studies) which do not involve continuous or repeated data collection and are not necessarily linked to a predefined action plan. However, some activities that do not meet these criteria for classification as "surveillance activities" can contribute to achieving the surveillance purposes listed in Table 2. It is therefore sometimes necessary to consider the information provided by surveillance activities together with the information provided by other types of activity (particularly surveys). It has also been suggested that a distinction should be made between surveillance activities and intervention activities (Dufour and Hendrikx, 2009). Surveillance and intervention are two distinct, but closely linked activities that are part of strategies to reduce or avoid the negative effects of disease (in other words "risk mitigation") (Häsler et al., 2011). This joint consideration of surveillance and intervention is particularly relevant for economic assessments of surveillance because the value of surveillance can only be assessed in the wider context of mitigation. Economic principles show that mitigation (defined as loss reduction achieved by surveillance and intervention) must be assessed with

Table 1
Definition of animal-health surveillance, monitoring, and different types of surveillance. (A complete list of the definitions of types of surveillance agreed in discussions at a workshop held prior to the ICAHS conference is included in the final workshop report, Hoinville, 2011.).

Type of surveillance	Definition
Early-warning surveillance	Surveillance of health indicators and diseases in defined populations to increase the likelihood of timely detection of undefined (new) or unexpected (exotic or re-emerging) threats. These are surveillance systems for the early detection of these threats.
Enhanced passive surveillance	Observer-initiated provision of animal-health data with active investigator involvement (e.g. by actively encouraging producers to report certain types of disease or by active follow up of suspect disease reports).
Monitoring	The systematic (continuous or repeated) measurement, collection, collation, analysis, and interpretation of animal-health and -welfare data in defined populations when these activities are not associated with a pre-defined risk-mitigation plan (although extreme changes are likely to lead to action).
Participatory surveillance	Participatory surveillance explores traditional information networks using participatory rural-appraisal methods (such as ranking, scoring, and visualisation techniques) to conduct risk-based, hazard-specific surveillance. The approach uses semi-structured interviews with key informants. This enables communities to provide their knowledge regarding health events, risks, impacts, and control opportunities by gathering qualitative health data from defined populations. The analysis of participatory data emphasises the comparison of information obtained from multiple informants; the method uses a variety of techniques to obtain the most likely interpretation of events. The objective is to enhance sensitivity by identifying cases based on a clinical case definition; these may then be evaluated and confirmed using either rapid tests in the field or laboratory diagnostics. Conventional epidemiological investigation techniques can be used to evaluate and confirm outbreaks detected by participatory surveillance as part of trace-back and trace-forwards activities.
Risk-based analysis	Use of prior or additional information about the probability of hazard occurrence[a] (including contextual information and prior likelihood of disease), to revise conclusions about disease status.
Risk-based prioritisation	Determining which hazards should be selected (for surveillance) based on information about the probability and the extent of (biologic and/or economic) consequences of their occurrence.[a]
Risk-based requirement	Use of prior or additional information about the probability of hazard occurrence[a] to revise the surveillance intensity required to achieve the stated surveillance purpose.
Risk-based sampling	Designing a sampling strategy to reduce the cost or enhance the accuracy of surveillance by preferentially sampling strata (e.g. age groups or geographical areas) within the target population that are more likely to be exposed, affected, detected, become affected, transmit infection, or cause other consequences (e.g. large economic losses or trade restrictions).
Risk-based surveillance	Use of information about the probability of occurrence[a] and the magnitude of the (biological and/or economic) consequence of health hazards to plan, design, and/or interpret the results obtained from surveillance systems. Risk-based surveillance can include one or several of the following four approaches (defined above) Risk-based prioritisation Risk-based requirement Risk-based sampling Risk-based analysis
Surveillance	The systematic (continuous or repeated) measurement, collection, collation, analysis, interpretation, and timely dissemination of animal-health and -welfare data from defined populations. These data are essential for describing health-hazard occurrence[a] and to contribute to the planning, implementation, and evaluation of risk-mitigation actions.
Syndromic surveillance	Surveillance that uses health-related information (clinical signs or other data) that might precede (or may substitute for) formal diagnosis. This information may be used to indicate a sufficient probability of a change in the health of the population either to deserve further investigation or to enable a timely assessment of the impact of health threats which may require action. This type of surveillance is not usually focused on a particular hazard, so can be used to detect a variety of diseases or pathogens-including new (emerging) diseases. This type of surveillance is particularly applicable for early-warning surveillance.

[a] The term 'occurrence' is used here to mean the prevalence or incidence of health hazard, whether prevalence or incidence is appropriate will depend on the purpose of the surveillance.

regard to the substitution possibilities between surveillance and intervention (Howe et al., 2013). For optimal economic efficiency, surveillance and intervention activities should be combined to provide the level of mitigation (i.e. loss avoidance) that maximises social welfare.

Whether to include a definition of 'monitoring' as well as a definition of 'surveillance' was debated. Both monitoring and surveillance include similar key features (systematic collection, analysis, interpretation and dissemination of animal-health and welfare data from defined populations). There is more variation between definitions of monitoring than between definitions of surveillance. We have used a definition of monitoring that is very similar to our definition of surveillance to highlight the conclusion of our discussions about the main *difference* between surveillance and monitoring. This difference is that surveillance is done to inform decisions about interventions to mitigate risk (so an action plan is implicit), whereas monitoring is not commonly associated with a pre-defined action plan. The justification for collection of data with no associated action plan was questioned. It was decided that monitoring may be appropriate for hazards that do not pose an

Table 2
Characteristics that can be used for describing surveillance activities. (A complete list of the characteristics that can be used to describe surveillance activities agreed in discussions at a workshop held prior to the ICAHS conference is included in the final workshop report, Hoinville, 2011.).

Description characteristic	Definition and options
Geographical area included	*Local*: an area within a country (e.g. border post, surroundings of natural park) *National*: an entire country *International*: includes a number of countries
Pattern of disease occurrence	*Endemic*: The constant presence of a disease in the population of interest *Sporadic*: A known disease which occurs intermittently in an irregular or haphazard pattern *Exotic*: A previously defined (known) disease that crosses political boundaries to occur in a country or region in which it is not currently recorded as present *Re-emerging*: A previously defined (known) disease that is currently either absent or present at a low level, in the population in a defined geographical area – but that re-appears or significantly increases in prevalence *New (emerging)*: A previously undefined (unknown) disease or condition, which might result from the evolution or change in an existing pathogen or parasite (and therefore cause a change of strain, host range, or vector, or an increase in pathogenicity). This term would also apply to the emergence of any other previously undefined condition
Policy purpose	Describes how surveillance information is used by policy-makers to inform decisions about how best to support policy objectives (such as maintaining a healthy and sustainable food and farming industry; protection of the livelihood of producers and other value-chain stakeholders and of public health; and to support national economic development). The specific decisions that surveillance information can assist policy-makers with are: *Management of outbreaks*: whether additional control measures are required to limit the spread of an emerging- or exotic-disease outbreak *Informing trade*: whether to permit import or to support export of animals or animal products. This decision should be based on evidence about the prevalence and distribution of disease and about the risk of disease transmission through the commodity being traded. The purposes are to protect the indigenous population and to facilitate access to international markets *Prioritisation*: how to prioritise surveillance and control measures for different health hazards. The prioritisation should be based on the hazard level and the impacts on animal health and welfare, public health, trade and the wider economy. The prioritisation should use information about relative importance of hazards *Informing control*: whether existing control measures should be maintained, stopped, or changed to improve the efficiency of surveillance and risk mitigation. This may include providing reassurance about the absence of specified existing or new diseases (which could threaten animal health or welfare or public health) to confirm that risk mitigation is not required
Scope of surveillance activity	*Component:* a single surveillance activity used to investigate one or more hazards in a specified population *System or network:* a range of surveillance components (and the associated organisational structures) used to investigate a single hazard in a specified population *Portfolio:* a range of surveillance components (and the associated organisational structures) used to investigate more than one hazard in a specified population
Surveillance purpose	Describes the type of information that will be obtained (using a particular surveillance activity) about a health hazard, the options are; *Early detection/warning* of known (exotic or re-emerging) or unknown (new) disease *Substantiate freedom* from disease or infection *Describe the baseline level, distribution, and impact* of specified disease(s) *Describe changes in the health* of the population (including changes in health indicators or in the incidence of specified diseases) *Describe changes that might threaten the health* of the population. This may include changes in the population structure or in its exposure to risk factors *Detect cases* to facilitate control

immediate threat (e.g. use of antimicrobials in livestock). However, it is assumed that major changes in the incidence of such a hazard might trigger the implementation of interventions which will change the monitoring system to a risk-mitigation system (i.e. a surveillance system with associated interventions). Monitoring can be justified economically if the implicit value of non-monetary benefits accruing (e.g. "peace of mind") at least covers the costs. Monitoring can be seen as a kind of insurance in the minds of decision-makers and the general public if other types of observation (e.g. clinical observation) fail.

A variety of terms used to describe surveillance activities that are designed to detect the emergence of new diseases (in both animal and human populations) and the threat of bioterrorism were discussed. These included 'scanning surveillance', 'general surveillance', 'targeted surveillance', 'syndromic surveillance', 'indicator-based surveillance' and 'event-based surveillance'. The use of these (often related) terms in different countries at different times has caused confusion; the definitions proposed in this paper and the accompanying report are intended to reduce this confusion.

3.2. Scanning surveillance and early-warning surveillance

The term 'scanning surveillance' was pioneered in New Zealand (Morris et al., 2003) and adopted in the UK in 2003 (Gibbens et al., 2003) to describe 'monitoring the health of an animal population to detect the undefined or

unexpected in a timely way'. This definition has not been used much outside of Great Britain (GB), so it was agreed to replace this term with the more intuitive 'early-warning surveillance' to describe surveillance aimed at early detection of threats. This should help to clarify the description of surveillance activities and make it easier to identify when government intervention is justified. However, the term 'scanning surveillance' to refer to the component of 'early-warning surveillance' that is based on monitoring diagnostic submissions (to detect changes in health patterns caused by endemic, new, or re-emerging diseases) will continue to be used locally in GB.

The requirement for enhanced 'early-warning surveillance' has led to developments in the traditional 'indicator-based surveillance' methods and the introduction of 'event-based' methods (ECDC, 2005).

3.3. Syndromic surveillance

'Syndromic surveillance' (Mirhaji, 2009; Sosin, 2003) is a form of 'indicator-based surveillance' which has been widely used in public-health. This type of surveillance is effective for early detection of increases in the incidence of endemic disease (like influenza) and also for providing evidence about the health impact of environmental threats (like flooding). In theory, this form of surveillance could be used to detect undefined events (for which tests for specified pathogens cannot be used) and might also be a more cost-effective approach for the detection of unexpected events when those diseases are believed to be absent or at low prevalence (Saegerman et al., 2012). The effectiveness of syndromic surveillance for detecting emerging or exotic diseases is not yet established (Chretien et al., 2009). But, one example of the successful use of syndromic data for outbreak detection is the rapid detection of Bluetongue in the Netherlands; detection was based on clinical reports of disease in sheep (Elbers et al., 2008).

Several issues were raised in relation to the definition of 'syndromic surveillance'. Firstly, we defined 'syndromic surveillance' (Table 1) to include the use of both clinical and other forms of data. (Others have restricted the use of the term 'syndromic surveillance' to mean only the use of clinical data – with the term 'indirect surveillance' being used for surveillance based on other data types.) Secondly, the definitions of syndromic surveillance used in public-health often include the concept of the collection of 'real-time' data to facilitate early detection (Sosin, 2003). Although the meaning of the term 'real-time' is not clear, in the public-health field data are often available for analysis within 24 h. We did not include the phrase 'real-time' in our definition of 'syndromic surveillance' because data are not currently available so rapidly in animal-health as in human health. However, syndromic data are still likely to be available more quickly than diagnostic information so could contribute to earlier detection of disease outbreaks (Odoi et al., 2009).

3.4. Hazard-specific surveillance

Early-warning surveillance relies heavily on the use of 'general surveillance' methods which are not focussed on specific hazards. However, surveillance focussed on specific pathogens (defined in our discussions as 'hazard-specific surveillance') can also contribute to the detection of outbreaks. 'Hazard-specific surveillance' is used to investigate known (endemic, re-emerging, or exotic) diseases. Sentinel-surveillance systems to detect incursions of exotic disease (by use of serological tests) provide an example of 'hazard-specific surveillance' which is aimed at the detection of outbreaks. We propose that the term 'hazard-specific surveillance' should replace the term 'targeted surveillance'. Targeted surveillance was defined by Lysons et al. (2007) as surveillance designed to 'answer a specific question about a defined disease or condition to be detected using agreed mechanisms for detection' but has also been used to refer to surveillance that is focussed on high-risk groups (such as fallen stock in BSE surveillance). The terms 'specific' (OIE, 2012) or 'pathogen-specific' have also been used for surveillance aimed at the investigation of specified hazards; however, 'hazard-specific' is more informative than 'specific' and 'pathogen-specific' does not include surveillance for non-infectious diseases.

3.5. Event-based (media-based) surveillance

The use of so-called 'event-based' methods has been introduced as an alternative to the traditional 'indicator-based' methods described so far in the context of early warning (ECDC, 2005). These methods rely on the collation of unstructured media-based data. It has been suggested that the name 'event-based' is confusing and that 'media-based' is a more appropriate term to use. This would avoid confusion with other similar terms such as the use of 'event-based surveillance' (in French *surveillance événementielle*) which was recently introduced as an alternative term for passive surveillance in France and with our use of the term 'event-related' to describe sampling strategies that are prompted by events (such as movement of animals). The proposal to use the term 'media-based' surveillance as an alternative for 'event-based' surveillance is one of the issues that will require further discussion.

3.6. Active and passive surveillance

In addition to developments in the type of information collected, there have been changes in the methods used to enhance the ability to detect outbreaks. Data-collection methods have traditionally been classified as either 'active' or 'passive' (Dufour and Hendrikx, 2009) depending on whether the provision of data is investigator-initiated (active) or observer-initiated (passive). 'Passive' surveillance systems (including the mandatory reporting of suspect cases) have been adapted to increase the likelihood of outbreak detection: therefore it has become difficult to classify the wide variety of surveillance activities as either 'active' or 'passive'. The use of the term 'passive' has also been viewed as misleading – implying that surveillance investigators are inactive; this has resulted in several attempts to change the way in which the origin of the data is described. The terms 'proactive' and 'reactive' have been proposed as alternatives for 'active' and 'passive'; more recently the terms 'surveillance programmed' and

'event-based surveillance' were proposed in France. The terms 'targeted surveillance' and 'scanning surveillance' have also been used (but as discussed earlier we discourage the use of these terms). Because the terms 'active' and 'passive' are well established, we recommend using these terms to describe investigator- and observer-initiated surveillance activities with the addition of the term 'enhanced passive' as described below.

The term 'enhanced passive surveillance' (Table 1) arose to describe 'passive' systems or components (e.g. mortality data collected by the producer) that have been fine-tuned by the investigator to standardise and better use the information obtained (Ouagal et al., 2010). 'Enhanced passive' has been used to describe either surveillance systems or their components. 'Enhanced passive' surveillance systems are used to capture trends emerging from otherwise seemingly isolated disease events or syndromes. In isolation, a set of symptoms might be of minimal concern – but awareness that syndromes are co-occurring in multiple locations or data sources might initiate a different level of investigation. Any activities encouraging opportunities either for regional awareness or for assessment of disease events or syndromes may be considered examples of an 'enhanced passive' system. The data collection is driven by the producers and their veterinarians, but the overseeing investigator coordinates the review of veterinary concerns or syndromic findings routinely compiled from multiple locations. Thus, the 'passive' system is enhanced through active oversight.

In contrast to this use of the term 'enhanced passive' to refer to surveillance *systems*, an 'enhanced passive' surveillance *component* is a single surveillance activity in which data provision is initiated by the observer but in which the quality of the data provided is improved by the investigator (to enhance its use in surveillance). Examples include regular active encouragement of producers to report certain types of diseases or specification and recording of data so it can be shared easily with surveillance investigators (Ouagal et al., 2010). The investigator requests the type and format of information to be shared; the producer participates by agreeing to share routine health (or risk-factor) data (on either a pre-set or sporadic basis). 'Active observational surveillance' has been proposed as an alternative term to describe this type of 'enhanced passive' component.

3.7. Risk-based surveillance

Another term which generated a considerable amount of discussion is 'risk-based surveillance' (Stärk et al., 2006). Our discussions clarified that the word "risk" used in these definitions implies the probability and consequence of events (as used in risk-analysis), rather than just the probability of events (as used in epidemiology). This relationship between 'risk-based' surveillance and the risk and consequence of disease implies that risk-based methods are likely to be applicable to known threats; the question of whether risk-based approaches can be used for emerging diseases requires further discussion. The discussions concluded with the observation that the proposed use of the term 'risk-based surveillance' captures four different ways in which risk information can improve surveillance (Table 1). It is likely that terms proposed under the category 'risk-based surveillance' will benefit from further discussion as methods are refined and field applications are reviewed.

Based on the workshop discussion 'risk-based surveillance' includes both approaches to inform strategic decisions including:

- 'Risk-based prioritisation' (examples of its use are provided by Mckenzie et al., 2007; Cardoen et al., 2009; by European Food Safety, 2011; Humblet et al., 2012);
- 'Risk-based requirement' (an example in Schwermer et al., 2009);

And to inform operational decisions including:

- 'Risk-based sampling' (used by Alban et al., 2008; Benschop et al., 2008; Tracey, 2010); The term 'risk-based sampling' was introduced to replace the term 'targeted surveillance' which has been used with multiple meanings (see our discussion above of 'hazard-based surveillance' definition). Since the workshop it has become clear that it is going to take a while to discourage the term 'targeted surveillance' which is currently widely used. We would suggest that in the interim the meaning of the term targeted should be clarified using 'targeted (hazard-specific)' or 'targeted (risk-based)';
- 'Risk-based analysis' described by Gustafson et al. (2010).

All four of these risk-based approaches use information about risk to improve either the efficiency of surveillance or its conclusions – although at different points or for different reasons in the surveillance process.

One of the main issues discussed was whether approaches other than 'risk-based sampling' (i.e. 'risk-based prioritisation', 'requirement' and 'analysis') should be included within the definition of 'risk-based surveillance'. To date, the term 'risk-based surveillance' has been used mainly to describe what we have called 'risk-based sampling'; it is likely that this use of the term will continue. It was generally agreed that all four approaches should be included in the recommended definition of 'risk-based surveillance'. Separating these different components of 'risk-based surveillance' helps to clarify the different ways in which risk can be used in the design and analysis of surveillance activities. This should allow the different options that are available to reduce costs or improve efficacy of surveillance applications to be identified. Additionally, because each approach relies on a unique set of methods, further field use and methodological development of the separate approaches would benefit from a clear distinction in terms.

Although consequences are generally taken into account in when considering 'risk-based prioritisation' it has been suggested that consequences do not need to be taken into account when designing a 'risk-based sampling' strategy. We could not reach unanimous agreement about whether or not consequences (e.g. the likelihood of disease transmission from a holding) should be considered when designing a 'risk-based sampling' strategy, although it was

suggested that this might depend on the purpose of the surveillance activity. The impact of consequences is likely to be important for surveillance designed to detect outbreaks, for example – but might be of lesser importance for surveillance designed to substantiate freedom. Both of these issues relating to 'risk-based surveillance' would benefit from further debate.

3.8. Sentinel surveillance and participatory surveillance

Sentinel surveillance is used to assess disease levels or spread. Sentinel surveillance is characterised by the repeated collection of data or samples from selected sites; these sites act as proxies for the entire population. Sites may be selected randomly or use volunteers as in the well-established public-health examples used to detect changes in the incidence of influenza through the Influenza-like Illness Surveillance Network (ILINet) in the USA. Alternatively efforts may be directed towards animals or premises that provide an increased probability of detecting a disease if disease is present (thereby enhancing cost-effectiveness); the latter is an example of 'risk-based sampling'. Risk-based sentinel surveillance has been used in areas in which the probability or importance of detection is increased (such as the margins of disease-free and endemic areas or the borders between high-prevalence and low-prevalence areas). The sampling of cattle herds in Switzerland in areas thought to be at high risk of Bluetongue incursion is one example (Racloz et al., 2008). The risk-based selection of sentinels can also be based on husbandry system, as in the use of free-range pig farms to demonstrate freedom from *Trichinella* (Alban et al., 2008). Sentinel surveillance requires repeated visits to the sentinel sites and consequently this activity requires a commitment from producers to allow such visits and/or the regulatory authority to make such visits. This can influence the design of sentinel surveillance systems. For example, selection of sentinel herds for the National Arbovirus Monitoring Programme (NAMP) in Australia (Kirkland, 2004) is based on the availability and interest of the regulatory field veterinarian in the area and on the willingness of producers to participate (as well as on the history of viral activity in the area). Incentives to encourage producers to participate (including cash compensation or free or reduced-cost diagnostic testing) might help in retention of sentinel surveillance sites. Some variation in the terms used to describe this type of surveillance was identified: the term 'pointed site surveillance' is used in China (personal communication, Martin Vincent, 2011).

'Participatory surveillance' (Table 1) is a new methodology based on participatory rural-appraisal methods; no existing definition was identified. The definition included in the report was developed by those with experience in the use of this method. These methods have been referred to as 'participatory disease surveillance' but a decision was made to change this to 'participatory surveillance' which will have wider application to all health-related issues. We hope that inclusion of this term in the list of definitions will improve awareness and understanding of this method and facilitate wider use of these methods.

3.9. Policy and surveillance purpose

Workshop participants also discussed categorisation of the purpose of surveillance (Table 2). The term 'purpose' was used (rather than 'objective') to distinguish these broad categorisations of reason for surveillance from the more specific objectives of individual surveillance activities. The purpose of surveillance determines the most appropriate surveillance approach; therefore it is essential (when designing or carrying out a surveillance activity) that the purpose of the surveillance is clear and that this purpose meets stakeholders' requirements. One of the issues highlighted was the need to distinguish between the '*surveillance purpose*' (which describes what type of information will be provided) and the '*policy purpose*' (which describes how this information will be used to support decisions). Some additional benefits of carrying out surveillance were included in the list of surveillance purposes; we decided these should be referred to as 'additional benefits' because they are not the primary reason for a surveillance system. These benefits include hypothesis generation, identification of risk factors, improved understanding of disease epidemiology (e.g. following emergence of a new disease) and facilitating epidemiological and laboratory research.

3.10. Scope of surveillance and geographical coverage

The discussions at and after the ICAHS workshop identified considerable variation in the way the 'scope of surveillance activity' and 'geographical area covered' were described. Scope is defined in the Oxford Dictionary (http://oxforddictionaries.com/definition/english) as 'the extent of the area or subject matter that something deals with or to which it is relevant'; 'scope' could therefore include a determination of which species to survey, hazards to include, geographical area covered (Dufour and Hendrikx, 2009), and time frame covered. We have used the term 'scope of surveillance activity' (Table 2) to describe the number of surveillance activities and health conditions included. Separate description characteristics are used to describe the geographical area, time frame, and species included.

There was no clear consensus about the meaning of the various terms which have been used to describe the scope of surveillance. In line with the definitions proposed by Martin et al. (2007) we propose that the term 'component' should be used for a *single* activity covering one or more health hazards. The terms 'system' or 'network' could be used to describe several surveillance activities covering a single health hazard; the terms 'strategy' or 'portfolio' could be used to describe several surveillance activities covering *more than one* health hazard. The term 'programme' is currently used with different meanings in different countries, so we did not include this in our proposed classification of 'scope'. We used the term 'portfolio' to refer to a range of surveillance activities aimed at investigating a range of threats. We suggest that where the term 'programme' is used its meaning should be stated.

There was also variation between countries in the terms used to describe the 'geographical area covered' by a

surveillance activity. There was general agreement about the meaning of 'local', 'national' and 'international' surveillance (Table 2). However, the use of the terms 'provincial' and 'regional' was not consistent. 'Regional' has been used to indicate surveillance in a small number of countries corresponding to a geographical or political entity (Dufour and Hendrikx, 2009) and also for areas within a country (such as "Eastern England"). Surveillance covering areas within a country has also been described as 'provincial'.

3.11. Pattern of disease occurrence

We based our definition of a 'new (emerging)' disease (Table 2) on that used by King (2005) – which does not distinguish between the emergence of a completely new disease and a change in the nature of an existing disease. However, these previously unknown 'emerging' diseases are distinguished from 'exotic' diseases (previously known diseases that emerge in a geographical area in which they are not usually known to be present) and from re-emerging diseases (diseases previously known in an area and that reoccur in that area after a period of absence). The definitions used by the OIE animal-health code and the EU (OIE, 2012) do not distinguish 'new (emerging)' diseases from 'exotic' diseases – but we believe this distinction is important. This is because the surveillance approaches suitable for the detection of exotic diseases might be different from those that can detect new diseases. In addition the surveillance approaches suitable for an emerging disease that arise from a change in the nature of an existing disease (e.g. a new strain or influenza), might be different from the approaches suitable for new (previously unknown) diseases that are not related to any previous diseases. If this is the case, then two separate definitions for 'new' and 'emerging' diseases might be useful. This is one of the issues that will be discussed during the next review of the definitions document.

3.12. Evaluation attributes

The final group of definitions discussed was the evaluation attributes. It was more difficult to prioritise which evaluation attributes (e.g. 'timeliness' or 'sensitivity') were most important than it was to decide which surveillance characteristics (e.g. 'surveillance purpose' or 'origin of data') were important. The main disagreement centred on whether more weight should be given to attributes used to assess the organisation of a system (e.g. 'organisation and management' or 'data collection processes') or to the attributes used to assess the performance of a system (e.g. 'cost' or 'impact'). It was agreed that the priority will vary depending on the purpose of the evaluation; hence, the purpose of any evaluation of animal-health surveillance should be clearly identified. This relationship between evaluation attributes and surveillance purpose was explored in the development of the SERVAL evaluation framework (Drewe et al., 2013).

When considering which surveillance – performance attributes were most important, many workshop participants thought that 'costs' and 'impact' were highly relevant, but the 'benefits' less so. This clearly demonstrates the "veterinary scientist" thinking: if something can be done (e.g. a surveillance system implemented with an acceptable sensitivity to detect disease), this then must be "good". But technical efficiency is not the same as economic efficiency; veterinary scientists tend to focus mainly on technical efficiency. Economic principles provide a robust and logical foundation to maximise people's well-being when allocating resources to animal-health surveillance. Economic-efficiency criteria (Table 3) relate the social values of economic products (benefits) and the scarce resources (costs) that provide the product to the technical relationships between them (production functions). Applying these criteria, decision-makers have more comprehensive information for their resource allocation decisions than is possible by just looking at 'impact', 'costs' or 'benefits' alone (Howe et al., 2013). The detailed definitions of 'sensitivity', 'specificity' and 'timeliness' were also discussed.

3.13. Sensitivity

The definition of 'sensitivity' discussed at the workshop (Table 3) was adapted from that used by the CDC (German et al., 2001) which considers sensitivity on two levels. First, when the purpose is to monitor the level of health-related events or to detect cases to facilitate control, 'sensitivity' refers to the proportion of those individual animals or herds that have the health-related condition of interest and that are detected by the surveillance system. This 'surveillance sensitivity (case detection)' will depend on the diagnostic-test sensitivity and the coverage of the surveillance system. Secondly, to detect a significant increase in the incidence of health-related events, 'surveillance sensitivity (outbreak detection)' has been defined as the probability that a surveillance system will detect a significant increase (outbreak) if one occurs (Buckeridge, 2007). In animal-health, there is a further interpretation of 'sensitivity' used for surveillance systems to substantiate freedom from disease (or infection). This sensitivity is the probability that disease (or infection) will be detected if present at a certain level in the population; 'surveillance sensitivity (presence)'.

It was suggested that having one term to describe these different interpretations of sensitivity is confusing and that the term 'sensitivity' should be replaced with the term 'detection fraction' or 'detection proportion' when referring to the ability to detect cases. However, 'sensitivity' is being used to describe case detection in a very similar way to the use of this term when describing the ability of diagnostic tests to detect affected individuals or groups. In addition 'sensitivity' has been used by others to describe this evaluation attribute (Vilas and Pfeiffer, 2010; German et al., 2001; Lynn et al., 2007). We therefore suggest that 'sensitivity' be retained – but that this attribute be split into the three sub-terms described above. This is another area that might require further discussion in the future.

3.14. Specificity and timeliness

The 'specificity' of a surveillance system was included for discussion at the workshop, but this subsequently was

Table 3
Attributes that can be used for evaluating surveillance activities. (A complete list of the attributes that can be used to evaluate surveillance activities agreed in discussions at a workshop held prior to the ICAHS conference is included in the final workshop report: Hoinville, 2011.).

Evaluation attribute	Definition
Economic efficiency	Whether the surveillance system produces the desired effect without wasting resources. Three levels of economic efficiency can be defined: *Optimisation*: maximising the net benefit to society achieved by the allocation of scarce resources to animal-health surveillance and intervention to avoid losses resulting from animal diseases. *Acceptability*: ensuring that the benefits generated by a mitigation policy at least cover its costs. This is commonly assessed using cost-benefit analysis. *Cost-minimisation*: ensuring that a technical target for disease mitigation (e.g. time to detection) is achieved at minimum cost without quantifying the benefit in monetary terms. This can be assessed using cost-effectiveness or least-cost analysis.
False-alarm rate	Proportion of negative events (e.g. non-outbreak periods) incorrectly classified as events (outbreaks). This is the inverse of the specificity but can be more easily understood than specificity.
Sensitivity	Sensitivity of a surveillance system can be considered on three levels. Surveillance sensitivity (*case detection*) refers to the proportion of individual animals or herds (in the population of interest) that have the health-related condition of interest and that the surveillance system is able to detect. Surveillance sensitivity (*outbreak detection*) refers to the probability that the surveillance system will detect a significant increase (outbreak) of disease. This requires a clear definition of what constitutes an outbreak. Surveillance sensitivity (*presence*) refers to the probability that disease will be detected if present at a certain level (prevalence) in the population.
Timeliness	Timeliness can be defined in various ways This is usually defined *as the time between any two defined steps* in a surveillance system. The time points chosen are likely to vary depending on the purpose of the surveillance activity. For outbreak detection this can be defined using various time points (e.g. the time between exposure to the infectious agent and the initiation of risk-mitigation measures, or the time between when disease could have been detected and reported and the time when it actually was reported). For planning purposes timeliness can also be defined as *whether surveillance detects changes in time for risk-mitigation* actions to reduce the likelihood of further spread. The precise definition of timeliness chosen should be stated as part of the evaluation process.

replaced by the term 'false-alarm rate' (Table 3) (the inverse of the specificity). It was thought that this latter term would be easier for planners and policy makers to understand.

The definition of 'timeliness' (Table 3) generated debate both during and after the workshop. It was felt that some previous definitions had been too prescriptive and that it might be better to define 'timeliness' simply as 'the time between any two defined steps in a surveillance system'. The time steps chosen are likely to vary depending on the purpose of the surveillance activity. For example, for outbreak detection, 'timeliness' could be defined as either the time from introduction of the agent to its detection (Jackson et al., 2007) or (alternatively) as the time between when the agent realistically first could have been detected (and reported) and the time when it actually was reported. A variation on this was suggested for planning purposes: that 'timeliness' can be used to determine whether a surveillance system detects and reports disease quickly enough to initiate interventions that reduce the probability of further spread. For other surveillance purposes (such as demonstration of disease freedom), it may be sufficient to consider the 'timeliness' of the surveillance process (such as time between sampling and reporting) and to place less emphasis on the infection process (Jajosky and Groseclose, 2004). This need to vary the definition of timeliness depending on the purpose of the surveillance activity makes this flexible definition appealing – but does require that the precise definition and chosen time points should be clearly stated as part of the evaluation process.

4. Conclusions

The availability of agreed-upon definitions of surveillance terms avoids confusion and facilitates essential communication, exchange of information, and comparison and evaluation of surveillance activities (across sectors, industries, and countries). This will build confidence in the validity of surveillance information and facilitate the engagement of all stakeholders (those who might influence or be affected by surveillance).

The proposed definitions are based, wherever possible, on those currently used in public- and animal-health surveillance. Very few inconsistencies were identified between the terms used in different disciplines during the final review of the report. However, there appeared to be more variation in the use of terms between geographical regions. The extension of the discussions to achieve broad geographical coverage will be important to facilitate the use of surveillance information to support trade.

Our discussions highlighted inconsistencies in the use of surveillance terms. Inconsistencies included the use of different terms to describe the same concept and situations in which one term is used with several distinct meanings. A prime example of the latter is 'targeted surveillance', we suggest that this term should be avoided – although we acknowledge that this may take time so in the interim we would suggest that the meaning of the term 'targeted' should be clarified using 'targeted (risk-based)' or 'targeted (hazard-specific)'.

Our agreed-upon definitions are intended to provide clear, comprehensive explanations of different aspects of the surveillance process; however some workshop participants required shorter, simple definitions that could be applied to their particular setting. It was agreed that this issue could be addressed using the ICAHS report as a reference document with individual users adapting the definitions as required – but retaining consistency with the concepts as defined in the ICAHS report.

Issues for further discussion include: the various components of 'risk-based surveillance'; whether the consequences of disease should be taken into account when designing risk-based sampling strategies; whether risk-based approaches are applicable for emerging disease; whether the 'sampling strategy' and 'whether surveillance is risk-based' would be better combined as one description characteristic; whether the term 'event-based surveillance' should be replaced with the term 'media-based surveillance'; whether separate definitions are required for 'new' and 'emerging' diseases; whether the new terms introduced to describe the various types of 'surveillance sensitivity' are useful and; whether the definition of 'timeliness' requires further clarification (possibly by developing sub-types similar to those used for surveillance sensitivity).

We understand that dissemination to and adoption by the wider community of the agreed-upon definitions and terms will take time; translation into other languages might help.

Conflict of interest

All authors declare that they have no conflicts of interest relevant to this paper.

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