Definition of Poultry

Poultry means all domesticated birds, including backyard poultry, used for the production of meat or eggs for consumption, for the production of other commercial products, for restocking supplies of game, or for breeding these categories of birds, as well as fighting cocks used for any purpose” (OIE, 2011). 

Official control of poultry diseases

Official control for animal diseases is defined by the International Organization for Animal Health (OIE) as “a programme which is approved, and managed or supervised by the Veterinary Authority of a country for the purpose of controlling a vector, pathogen or disease by specific measures applied throughout that country, or within a zone or compartment of that country”.

A zone is a subpopulation of animals kept in part of a territory with a given disease status requiring surveillance, control and biosecurity for the purpose of international trade. A compartment is a subpopulation of animals kept under a common biosecurity system with a given disease status requiring surveillance, control and biosecurity for the purpose of international trade (OIE, 2011).

The following criteria for listing diseases in the list of reportable diseases are found under Article 1.2.1 of the Terrestrial Animal Health Code (OIE, 2011):

- International spread while some countries remain free of the disease e.g. virulent Newcastle Disease
- Zoonotic potential with human consequences e.g. Salmonella Enterica serovar enteritidis
- Significant spread within naïve populations with significant morbidity or mortality e.g. vvIBD
- Emerging diseases with zoonotic potential or expanded distribution e.g. HPAI H5N1 subtype

Avian diseases considered reportable by OIE in Article 1.2.1 include the following diseases:

- Avian chlamydiosis
- Avian infectious bronchitis
- Avian infectious laryngotracheitis
- Avian mycoplasmosis (Mycoplasma gallisepticum)
- Avian mycoplasmosis (Mycoplasma synoviae)
- Duck virus hepatitis
- Fowl cholera
- Fowl typhoid

Highly pathogenic avian influenza in birds and low pathogenicity notifiable avian influenza in poultry as defined in Chapter10.4.

- Infectious bursal disease (Gumboro disease)
- Marek’s disease
- Newcastle disease
- Pullorum disease
- Turkey rhinotracheitis

The following table summarizes the prescribed diagnostic tests for avian species are defined by OIE in Chapter 1.3 of the Terrestrial Animal Health Code.
Where are the risks for importation of poultry pathogens? Broiler meat remains the most important poultry commodity traded globally (Cast, 2006). According to a recent review of the risk of importing poultry pathogens through chicken meat highly pathogenic avian influenza (HPAI), Newcastle disease (ND), and infectious bursal disease-1 (IBDV-1) represent pathogens with the highest risk (Cobb, 2011). Even though HPAI and vND are likely to cause embryo death, the possibility of fomite transmission also exists.

With proper practice of breeding flock hygiene HPAI, ND and avian mycoplasmosis (due to *Mycoplasma gallisepticum* or *M. synoviae*) have been proposed to be most likely to be spread through trade in eggs (Cobb, 2011).

Important pathogens related to food safety which have economic and public health impact are also important from a trade perspective. For example, the EU program for controlling zoonotic pathogens from poultry and hatching eggs include *Salmonella enteritidis*, *Salmonella hadar*, *Salmonella infantis*, *Salmonella typhimuriumand*, *Salmonella Virchowsince* 2007 (EU, http://ec.europa.eu/food/animal/liveanimals/poultry/leaflet%20hens_2.pdf).

**Factors affecting export strategies**

Export implies the ability to prevent entry or to limit and eradicate a disease based on zoning or compartmentalization once present. Since 1994, the World Trade Organization, Sanitary and Phytosanitary Measures Agreement (SPS) govern international trade in poultry and poultry products with the removal of the General Agreement on Tariffs and Trade (GATT). The costs of disease eradication include the current epidemiological situation including the risks of re-introduction, the capacity of government veterinary services, availability of vaccine and diagnostic laboratory capacity in the country (McLeod, 2001). A policy to demonstrate freedom from disease may be necessary to support national needs of poultry industry, to protect or expand existing trade, to support domestic production and to alleviate poverty (McLeod, 2001). Each of these reasons has associated costs and benefits.

SPS is intended to protect the health and life of animals, humans and plants. SPS Measures are implemented with consideration for harmonization, equivalence, assessment of risk and determination of the appropriate level of sanitary or phytosanitary protection, adaptation to regional conditions, transparency, control, inspection and approval. Countries are to consider special needs of developing countries and consultations and dispute mechanisms are also included.

Vertically integrated poultry production systems are likely to export based on the basis of compartmentalization. Before compartmentalization can be undertaken the following issues require consideration (OIE, 2007):

- Public-private partnerships;
- Traceability;
- Certification system;
- Good biosecurity practices are specified;
- Site-specific biosecurity plans.

**Table 1 - Tests prescribed by OIE for reportable avian diseases.**

<table>
<thead>
<tr>
<th>Terrestrial Code Reference</th>
<th>Disease</th>
<th>Prescribed Tests</th>
<th>Alternative</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.11</td>
<td>Infectious Bursal Disease</td>
<td>-</td>
<td>AGID; ELISA</td>
</tr>
<tr>
<td>10.12</td>
<td>Marek’s Disease</td>
<td>-</td>
<td>AGID</td>
</tr>
<tr>
<td>10.5</td>
<td><em>Mycoplasma gallisepticum</em></td>
<td>-</td>
<td>Agg; HI</td>
</tr>
<tr>
<td>10.10</td>
<td>Fowl Typhoid and Pulmonary</td>
<td>-</td>
<td>Agg; Agent ID</td>
</tr>
<tr>
<td>10.2</td>
<td>Avian Infectious Bronchitis</td>
<td>-</td>
<td>VN; HI</td>
</tr>
<tr>
<td>10.3</td>
<td>Avian Infectious Laryngotracheitis</td>
<td>-</td>
<td>AGID; VN; ELISA</td>
</tr>
<tr>
<td>10.4</td>
<td>Avian Influenza</td>
<td>Virus isolation with pathogenicity testing</td>
<td>AGID; HI</td>
</tr>
<tr>
<td>10.13</td>
<td>Newcastle Disease</td>
<td>Virus isolation</td>
<td>HI</td>
</tr>
</tbody>
</table>

(-) No Test Designated Yet
The Veterinary Services of a country must be evaluated in order to assess its ability to implement compartmentalization, including the following issues (OIE, 2007):

- Legislative and administrative infrastructures;
- Independence in the exercise of official functions;
- Coordination capability;
- Adequate technical and financial resources;
- Disease surveillance and diagnostic capability;
- Knowledge of relevant animal production and non-production sectors;
- Systems for the early detection of disease and emergency response;
- Effective consultation with stakeholders;
- Performance history, including the timeliness and accuracy of disease reporting.

**Epidemiological and laboratory diagnostic requirements**

Essential epidemiological approaches include assessing the characteristics of the host population, agent surveillance and monitoring and environmental factors (Welte, 2000).

**Characterize the population at risk**

The host population is described in relation to its intrinsic and extrinsic characteristics. Basic demographic census data is required to define the poultry population at risk as accurately as possible and must be linked with surveillance data generated in order to support disease freedom. Intrinsic factors to consider include descriptors of genetics and demographic factors including age, sex and the production stage and type. Extrinsic factors include marketing systems, interaction with smallholder poultry subpopulations and interaction with wildlife, management system and the intended use of poultry.

**Conduct effective surveillance**

Surveillance provides essential data that is a key input for import risk assessment of trading partners. Surveillance is the systematic ongoing collection, collation and analysis of data and the timely dissemination of information to those who need to know so that action can be taken (OIE, 2011¹). A survey shares similar features with surveillance but is limited in time and scope in order to provide useful information at a minimum cost of human and financial resources. Monitoring is also similar to surveillance but does not require that action be taken. The potential objectives of surveillance include detecting emerging disease, assess disease trends, assess the burden of disease, define disease priorities and to evaluate disease control programs (including support of poultry export programs). Surveillance data may be collected either actively and passively from field sources or from laboratories. Data may be collected using surveys, through routine collection at markets and slaughter facilities, through sentinel surveillance and through submissions from private veterinarians and poultry companies. In addition, secondary data from laboratory specimen banks and laboratory records are very useful to assess disease trends and recent status.

It is important to emphasize that passive surveillance in smallholder and intensive production systems is very effective and cost efficient in detecting disease in comparison with active surveillance systems. Poultry owners and farm managers play a vital role in recognizing and monitoring production and clinical signs that can strongly promote early recognition and detection of poultry disease. Therefore, the active engagement of farmers, companies and communities is the essential component of an effective surveillance system. Successful surveillance requires that public and private sectors define their roles and responsibilities through partnership agreements.

Public-private partnerships are essential in order to design, develop and implement a credible surveillance system, which supports a favorable risk assessment to promote trade. Interaction among field and laboratory staff in both sectors is a key functional element of the surveillance system.

Regulatory services must have authority through enabling legislation, provide a trained workforce that can conduct outbreak investigations and is capable of managing a surveillance system from local to central levels. Epidemiology and laboratory diagnostic competencies must include the ability to collate and analyze surveillance data using computers and information systems. Data provides information that generates knowledge and understanding to inform evidence based-decision making. For a surveillance system to work, it is essential that data flow in both directions so that data providers also receive feedback. The following figure depicts such a model (OIE, 2011²):
Adequate individual and institutional capacity is required in both public and private sectors in order to support a comprehensive and credible surveillance system. The surveillance system must be responsive to changing needs related to international and bilateral trade issues. International standards for conducting surveillance and diagnosis of important poultry diseases are available for further reference (OIE, 2011², 2011³).

Surveillance data is needed to provide performance-based indicators to support evidence-based decision making for industry and government. Surveillance directly informs risk analysis and can indirectly contribute to existing process control systems such as hazard analysis critical control points (HACCP) and on-farm good agricultural practices (GAP). Physical, chemical and biological hazards can be considered under an all-hazards approach. Biological hazards considered for the purposes of the following discussion.

Assess environmental factors

Environmental factors can be strongly influenced through the effective application of sound biosecurity procedures. Physical factors include key features of air, water and land and climatic conditions that comprise the ecology of the poultry production systems. Man-made and natural features such as irrigation canals and natural water bodies hold particular importance for environmental persistence of viruses and bacteria affecting poultry and humans. Vectors including wildlife and insects constitute an important potential source of disease pathogens and for disease transmission in the poultry environment. Industry characteristics related to vertically integrated poultry production include feed, maintenance and service companies, transportation, biological and pharmaceutical interventions, health monitoring programs, carcass disposal, waste and litter management, rendering, processing and marketing systems. Record keeping and quality assurance are required to measure and assess the risks associated for each of these components.

The interactions among agent, host and environment differ for each poultry pathogen, indeed for strains and subtypes as well. How disease is expressed and detected in terms of morbidity and mortality depends on this triad of epidemiological interactions. Figure 2 illustrates the challenge of early detection and diagnosis of poultry diseases (Adapted: Salman, 2003).

Design and implementation of surveillance for poultry diseases requires a step-by-step approach. The nature and biology of the disease is the first consideration since sampling, detection and
probabilistic (e.g., surveys) and non-probabilistic (e.g., slaughter surveillance) methods to support the overall objectives of the surveillance system. Both are necessary and useful. For example, targeted submission of routine mortality from poultry houses provides valuable disease information among the most vulnerable in the population.

What sample size is needed to meet the objectives of a survey or for surveillance?

It is not possible to prove in absolute terms that a disease does not exist in a population. However it is possible to “estimate” freedom from disease at some defined upper limit or to estimate that a disease is not prevalent above some threshold value within a stated confidence interval. Two main considerations is designing surveillance are the validity and reliability of the estimates produced (Levy, 2008). Estimates must be both accurate and precise. The measurement process and measuring what we intend to, influence validity. Reliability of the estimates is influenced by the sample size. Random selection of samples is also essential so that inferences can be made about the population.

The diagnostic test chosen influences our ability to detect evidence of the disease pathogen from both intrinsic and epidemiological perspectives. The type of sample influences the estimate of apparent disease prevalence in a population. Serological tests as a historical marker of disease exposure will tend to increase the prevalence estimate while agent or antigen detection provides real-time data related to exposure with a lower estimate of apparent disease prevalence. It is critical that the appropriate test is applied in relation to species, cost, time constraints and overall objectives. The use of screening tests and confirmatory tests must also be considered. Tests may be combined in series or in parallel as part of a case definition. Since most diagnostic tests are imperfect and produce false-positive and false-negative reactions, sensitivity, specificity as well as predictive value positive and negative are needed to adjust sample size estimates accordingly to deal with this type of systematic error or bias.

Detection and diagnosis of poultry pathogens through surveillance

Surveillance data can be collected using both...
Assuming we are using a perfect test, the following formula is used to calculate a suitable sample size to detect the presence of disease (to prove freedom) using a perfect test (Thrusfield, 2008):

\[ n = \frac{1-(1-p_1)^d}{(1/d)} \{N-d/2\}+1 \]

where:

- \( N \) = Population size
- \( d \) = minimum number of expected animals expected in population
- \( n \) = required sample size
- \( p_1 \) = probability of finding at least one case in the sample

Extensive tables are also available (Cannon, 1982) to calculate sample sizes and probability for detecting disease assuming the use of a perfect diagnostic test.

For an imperfect test more complex equations are used and sample sizes are adjusted for the sensitivity and specificity of the test used and computer software has been developed to iteratively provide feedback on the probability of detection with different sample sizes (Cameron, 1999). Different formulae are used for an infinite population when sampling is done with replacement given by a binomial distribution (e.g. large serological surveys) or for finite populations without replacement given by a hypergeometric distribution (e.g. small surveys at slaughter facilities).

The usual “unit of interest” for poultry surveys and surveillance is the flock and individual animals that are sampled represent the flock as a whole. However for large surveillance programs that include smallholder and intensive production systems the unit of measure can be village, district, state or province.

Intensive and small holder poultry production systems are unique however they are inter-related at common points of contact through marketing, service and social channels influencing disease transmission in both developed and developing countries. The complexities of assessing the presence of disease or certifying freedom from disease in a zone or compartment in countries implies the need to assess all related components of these systems comprehensively. Bringing stakeholders together is a critical and challenging part of poultry disease surveillance design and implementation.

In some situations it may be appropriate to calculate sample size based on appropriate benchmarks of disease prevalence. In this case, precision and acceptable error must be specified. As noted previously, surveys can be done using simple random, systematic random, stratified, cluster and multi-stage sampling methods and justification for use depends on the technical objectives and methods, resource limitations as well as logistical and political considerations. “The method used to calculate sample size for surveys depends on the purpose of the survey, the expected prevalence, the level of confidence desired of the survey results and the performance of the tests used” (Article 1.4.4. OIE, 2011).

For a simple random sample size calculation is based upon the following equation for an infinite size population (Thrusfield, 2008):

\[ n = \frac{z^2 \cdot P_{exp} \cdot (1-P_{exp})}{d^2} \]

where:

- \( n \) = required sample size,
- \( P_{exp} \) = expected prevalence,
- \( d \) = desired absolute precision,
- \( z \) = multiplier from the Normal distribution

Note that population size is not included in the equation. Additional formulae are also available for other sampling methods and circumstances.

Sample size estimates may differ when considering acute versus chronic poultry disease that influences the current disease prevalence in the flock.

Flock size is also an important parameter and impacts sampling strategies and diagnostic testing in smallholder and intensive production systems. Technical and logistical factors must be weighed in each case and considered together in the overall surveillance plan. In order to detect at least one positive case of a disease in a flock, a larger proportion of the population must be sampled in smaller flocks than in larger flocks at a given estimate of apparent prevalence (Canon, 1982). Selecting which animals and how often to sample (or re-sample) depends on the objective of the survey as well as practical considerations such as field and laboratory capacity. Sample size may also be defined based on whether screening tests and confirmatory tests are used.

Availability of surveillance data can be a limiting factor for countries. New methods that incorporate quantitative and qualitative methods are being developed to support disease freedom through
stochastic decision tree modeling of surveillance system components (SSC) (Martin, 2007). In this approach, data sources include epidemiological records and expert opinion. Dealing with design prevalence is required using international standards, trading partner requirements, biological plausibility, production system characteristics, resources and political considerations. Since surveillance design is a complex process it is important to consult with epidemiologists and statisticians when designing and analyzing the results of the surveillance system.

The methods used will vary by the epidemiological situation and institutional capacity and needs of each country. Countries that can demonstrate historical freedom from a disease and countries that are progressively controlling to re-establish trade through compartmentalization will require different approaches, as seen in the following published examples related to highly pathogenic avian influenza (HPAI) H5N1 subtype.

**Scenario 1: Historically free of HPAI H5N1 subtype**

In this scenario, the national export strategy is to maintain and promote existing trade of poultry and poultry products through early detection in a country historically free of HPAI H5N1 subtype. There is official regulatory authority for H5N1. Six susceptible avian subpopulations at risk are identified including: (1) highly-intensive commercial poultry; (2) medium-intensive commercial poultry; (3) live bird market poultry production; (4) smallholder/backyard poultry; (5) wild birds; and (6) zoos and aquariums. Diagnostic tests used include (1) clinical screening; (2) antigen detection including rapid tests for Influenza A virus, RRT-PCR ELISA; and (3) antibody detection test including HI and ELISA. Suspect, presumptive and confirmed case definitions are established. Active and passive surveillance components including sampling methods are adapted for appropriate and effective response for each subpopulation including sample numbers, frequency and time interval. Formal surveillance programs, data management including analysis exists through existing poultry programs and through new programs in wildlife and zoo surveillance. Probability of detection for H5N1 within given timeframes for each subpopulation is estimated and reported for the surveillance program (USDA, 2007).

**Scenario 2: Progressive control of HPAI H5N1 subtype through compartmentalization**

In this scenario, the national export strategy is to re-establish trade of fresh poultry products. Official OIE and FAO guidelines are utilized to apply principles for surveillance and biosecurity to establish effective compartmentalization. An assessment is conducted of the following components: (1) potential pathways of virus introduction into commercial poultry systems; (2) farms are identified in a geographic information system; (3) feed management is described; (4) poultry health standards are established including veterinary supervision; (5) pest control standards are defined; (6) water supply standards are defined; (7) a traceability system is established; and (8) standard operating procedures for biosecurity management are developed. Roles and responsibilities of public and private sectors are clearly defined and farms apply for accreditation of compartments based on biosecurity and surveillance in order to establish and maintain an area free from notifiable avian influenza (NAI). Surveillance procedures are defined by test type, number of samples, frequency and time interval. Clinical surveillance in smallholder units with poultry is conducted semi-annually. Procedures are also established to maintain surveillance in buffer zones. Compartmentalization is gradually expanding in application under a voluntary adoption scheme (Ratananakorn, 2011).

Important observations of important considerations of the surveillance systems including flock size and diagnostic requirements are included in the scenarios summarized below:

- **Biology of the pathogen**;
- **The country disease situation and related objectives of the surveillance program**;
- **Role and responsibilities of public and private sectors are established**;
- **Each subpopulation and management system or zone has specific surveillance requirements**;
- **Both active and passive sample collection methods are used including regular clinical surveillance**;
- **Interaction among subpopulations is carefully considered when designing the surveillance system including the environment (e.g. sampling the environment is included in live bird market surveillance)**;
- **Sample size calculations are justified and appropriate for each subpopulation/compartment and specify number of primary sampling units (e.g., house) and secondary sampling units (e.g. poultry) at a given probability of detection and prevalence threshold**;
- **The surveillance system is both functionally effective and cost effective with consideration for practical limitations**;
Diagnostic tests used are aligned with the surveillance objectives;
Samples are collected, handled and analyzed according to international standards of practice;
Recognized diagnostic tests used are used at approved laboratories complying with international standards (OIE, 2011)
Tests selected for use are appropriate for the subpopulation in terms of species type and management system;
Testing frequency and time interval for each subpopulation considers the pathobiology of the disease, the characteristics of the production system, risk of exposure, incubation period, field test performance, transmission, costs and resources available.

Regular evaluation of surveillance systems is a critical need for the consideration of public and private animal health sectors since the drivers for disease introduction and transmission are dynamic in nature.

Conclusions
International guidelines governing epidemiology and disease diagnosis are the foundation for sound policy and practices related to both domestic and trade policies. These principles are applied uniquely in each situation and for each country. Epidemiological and diagnostic approaches to support export strategies are therefore specific and comprehensive and integrated in scope at the national level and the subpopulation level.

Epidemiological and diagnostic approaches are challenged to keep pace with national and international trends related to disease risk and trade. The trend toward larger poultry production units is occurring internationally while local, village and backyard production systems continue to meet local demands and needs for fresh and/or organically grown poultry and poultry products. There will be additional complexity and challenge for disease surveillance in peri-urban areas that provide poultry products for cities. Evaluation of surveillance systems is therefore a key need for the future.

Continued commitment to developing veterinary capacity in epidemiology and disease diagnosis is required for sustainable, evidence-based production and trade practices related to the animal-human-environmental interface.

References
THRUFSFIELD, M. (2007) Veterinary Epidemiology, Third
